TMDL Sediment Quality Assessment Study at the B Street/Broadway Piers, Downtown Anchorage, and Switzer Creek, San Diego

PHASE II

Final Report

TEMPORAL VARIABILITY, CAUSES OF IMPACTS, AND LIKELY SOURCES OF CONTAMINANTS OF CONCERN

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BCA BENTHIC COMMUNITY ANALYSIS
BRI BENTHIC RESPONSE INDEX
BIGHT'98 SOUTHERN CALIFORNIA BIGHT 1998 REGIONAL MARINE MONITORING SURVEY
BPJ BEST PROFESSIONAL JUDGMENT
BPTCP BAY PROTECTION AND TOXIC CLEANUP PROGRAM
BTAG BIOLOGICAL TECHNICAL ASSISTANCE GROUP
CBGV CONSENSUS-BASED SEDIMENT QUALITY GUIDELINE
COPC CONTAMINANTS OF POTENTIAL CONCERN
CSM CONCEPTUAL SITE MODEL
DDD DICHLORODIPHENYLDICHLOROETHANE
DDE DICHLORODIPHENYLDICHLOROETHYLENE
DDT DICHLORODIPHENYLTRICHLOROETHANE
DQO DATA QUALITY OBJECTIVES
EPA ENVIRONMENTAL PROTECTION AGENCY
ERL EFFECTS RANGE LOW
ERM EFFECTS RANGE MEDIAN
ERMQ EFFECTS RANGE MEDIAN QUOTIENT
GC/ECD GAS CHROMATOGRAPH/ELECTRON CAPTURE DETECTOR
GC/MS GAS CHROMATOGRAPH/MASS SPECTROMETER
HMWPAH HIGH MOLECULAR WEIGHT PAH
HPLC HIGH-PRESSURE LIQUID CHROMATOGRAPHY
HQ HAZARD QUOTIENT
LMWPAH LOW MOLECULAR WEIGHT PAH
LOE LINE OF EVIDENCE
MSD MINIMUM SIGNIFICANT DIFFERENCE
PAH POLYNUCLEAR AROMATIC HYDROCARBONS
PCB POLYCHLORINATED BIPHENYLS
PEL PROBABLE EFFECTS LEVEL
PELQ PROBABLE EFFECTS LEVEL QUOTIENT
PPB PARTS PER BILLION
PPM PARTS PER MILLION
PPPAH PRIORITY POLLUTANT PAH
PPT PARTS PER THOUSAND
RSD RELATIVE STANDARD DEVIATION
QA/QC QUALITY ASSURANCE/QUALITY CONTROL
SAP SAMPLING AND ANALYSIS PLAN

SCCWRP SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT
SDRWQCB REGIONAL WATER QUALITY CONTROL BOARD, SAN DIEGO REGION
SIM SELECTIVE ION MONITORING
SQG SEDIMENT QUALITY GUIDELINE
TCHLOR TOTAL CHLORDANE
TDDT TOTAL DDT
TEL THRESHOLD EFFECTS LEVEL
THS TOXIC HOT SPOT
TIE TOXICITY IDENTIFICATION EVALUATIONS
TMDL TOTAL MAXIMUM DAILY LOAD
TOC TOTAL ORGANIC CARBON
TPAH TOTAL PAH
TPCB TOTAL PCB
TRV TOXICITY REFERENCE VALUES
UPL UPPER PREDICTION LIMIT
WOE WEIGHT OF EVIDENCE

1.0 INTRODUCTON

Sediments in San Diego Bay in the vicinity of B Street/Broadway Piers, Downtown Anchorage, and near the mouth of Switzer Creek are contaminated with anthropogenic chemicals. In addition, these sites contain degraded benthic macroinvertebrate communities, and samples from these areas have been demonstrated to be toxic to various marine invertebrate species in laboratory toxicity tests. As a consequence, these sites have been identified as areas of impaired water quality. In response to this contamination, the San Diego Regional Water Quality Control Board (SDRWQCB) has initiated efforts to develop total maximum daily loads (TMDLs) for these sites in order to reduce ongoing loadings of contaminants of concern.

The SDRWQCB has initiated studies to determine the extent and potential source reduction and clean up requirements for the impaired environment. These efforts require similar information in order to initiate action: delineation of the spatial extent and magnitude of impairment, information on temporal variability of contamination and bioeffects, causes of impacts, and descriptions of the sources of contaminants. Such information is needed by the SDRWQCB in order to prioritize TMDL actions. Similar information is needed for remediation planning, so that the affected area can be defined, and effective clean-up standards established. The primary objective of these actions is elimination of the impairment of benthic animal communities. In addition, the SDRWQCB has determined that these efforts should also minimize human health and wildlife impacts resulting from the accumulation and possible biomagnification of contaminants in the food web.

This report discusses results of Phase II TMDL studies. Phase II monitoring emphasized a temporal assessment of marine sediments adjacent to the B Street/Broadway Piers, Downtown Anchorage and Switzer Creek areas in San Diego Bay. The purpose of this study was to examine temporal variability of chemical contamination of sediments and associated bioeffects, and to investigate causes of impacts in order to provide further information needed to plan TMDL and cleanup activities. This study was developed jointly by the University of California, Davis, the City of San Diego, the San Diego Unified Port District, and the SDRWQCB in an effort to minimize duplication of effort and to provide comparable data throughout San Diego Bay. This study was similar in scope and design to ongoing sediment assessment studies being conducted throughout San Diego Bay, and the approach followed methods described for other sediment TMDL studies, particularly those at the Chollas and Paleta Creek hotspots (SCCWRP et al 2004; Brown and Bay 2005).

The relationship of the proposed study, TMDL, and cleanup activities is shown in Figure 1-1. Phase I studies were designed to determine the magnitude and spatial extent of contamination and bioeffects. Spatial assessment information is an integral component of both cleanup and TMDL activities at the study sites, consequently this information will be obtained during the initial portions of the program (Phase I in Figure 1-1). The Phase I data was used to identify areas of greatest concern for detailed investigations to support the development of TMDLs (Phase II).

The purpose of this document is to provide a more detailed description of the Phase II investigations. These activities included laboratory research to identify causes of sediment toxicity (toxicity identification evaluations - TIEs), assessment of temporal patterns in contamination and associated bioeffects, and evaluation of likely sources of the contaminants of concern.

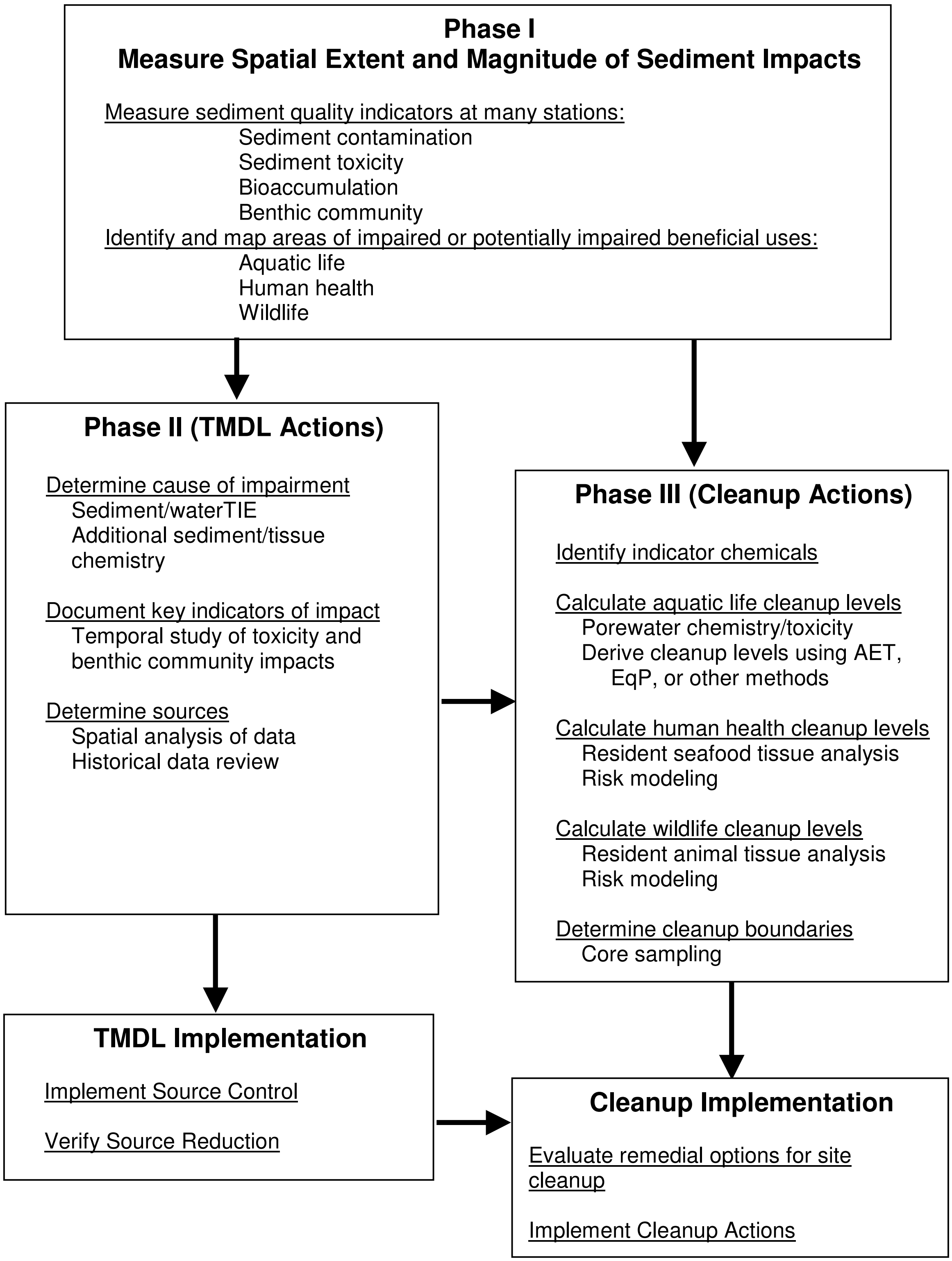


Figure 1-1. Relationship of study plan to potential subsequent TMDL and cleanup activities at the study sites.

Products from the Phase II studies and Phase III source identification and TMDL implementation will likely influence potential cleanup activities at the sites, through the identification of contaminants of concern and identification of ongoing contaminant sources. Studies that are being planned to support cleanup actions in other portions of San Diego Bay are expected to include the same components included in Phase I and II, plus additional studies necessary to derive numerical cleanup levels and determine the vertical extent of contamination (shown in Phase III). These Phase III studies may be conducted at a later date and at a reduced number of stations, depending upon the results of Phases I and II, in order to provide a more efficient and cost effective study design. Information in the Phase I and II SAPs describes the statistical analysis of the data for the purposes of determining the presence and extent of contamination or effects. However, procedures for the determination of numerical load reductions or clean up levels are not included; determination of these parameters requires the consideration of additional factors (e.g., costs and degree of protection desired) and is outside the scope of this study.

Detailed descriptions of the Phase II study design, field sampling effort, laboratory analysis, and data analysis procedures were included in the Phase II Sediment Assessment Plan. This SAP followed the general approach of the California Bay Protection and Toxic Cleanup Program (BPTCP) and the Bight'98 regional survey in measuring multiple indicators of sediment quality and using a weight of evidence approach to identify areas of impaired sediment quality. Included in this effort were determinations of the temporal patterns of:

- Sediment contamination
- Sediment physical/chemical characteristics (e.g., grain size, TOC)
- Sediment and interstitial water toxicity
- Bioaccumulation of contaminants by a marine invertebrate
- Altered benthic community composition

The four lines-of-evidence were ranked based on severity of impact used a tiered approach. This approach resulted from detailed discussions between the various stakeholders involved in the sediment TMDLs in San Diego Bay. The resulting categorizations for each indicator were then combined in a weight-of-evidence to arrive at overall categorizations for each site. This approach is described in (SCCWRP 2004).

The approach for determining causes of toxicity also involved a weight-of-evidence based on correlations between contaminant concentrations and bioeffects, tissue concentrations, and solid-phase and porewater TIEs. TIEs followed procedures developed by the U.S. Environmental Protection Agency, as well as novel techniques developed by UC Davis (MPSL-Granite Canyon).

1.1 BACKGROUND

The SDRWQB has established a cleanup plan for designated "known toxic hot spots" in San Diego Bay based on findings from the BPTCP. The cleanup plan provides definitions, rankings, and a preliminary assessment of actions for a number of sites around the bay. Under this definition, five specific areas were designated as toxic hot spots (THS), four with a ranking of moderate and one with a ranking of high. Many of the areas lie at the inlet of creeks or storm drains, indicating that stormwater may be a significant contributing factor. The three areas that are the focus of this study, one at the B Street/Broadway Piers, one in the vicinity of Downtown Anchorage, and one at the discharge of Switzer Creek, are shown in Figure 1-2.

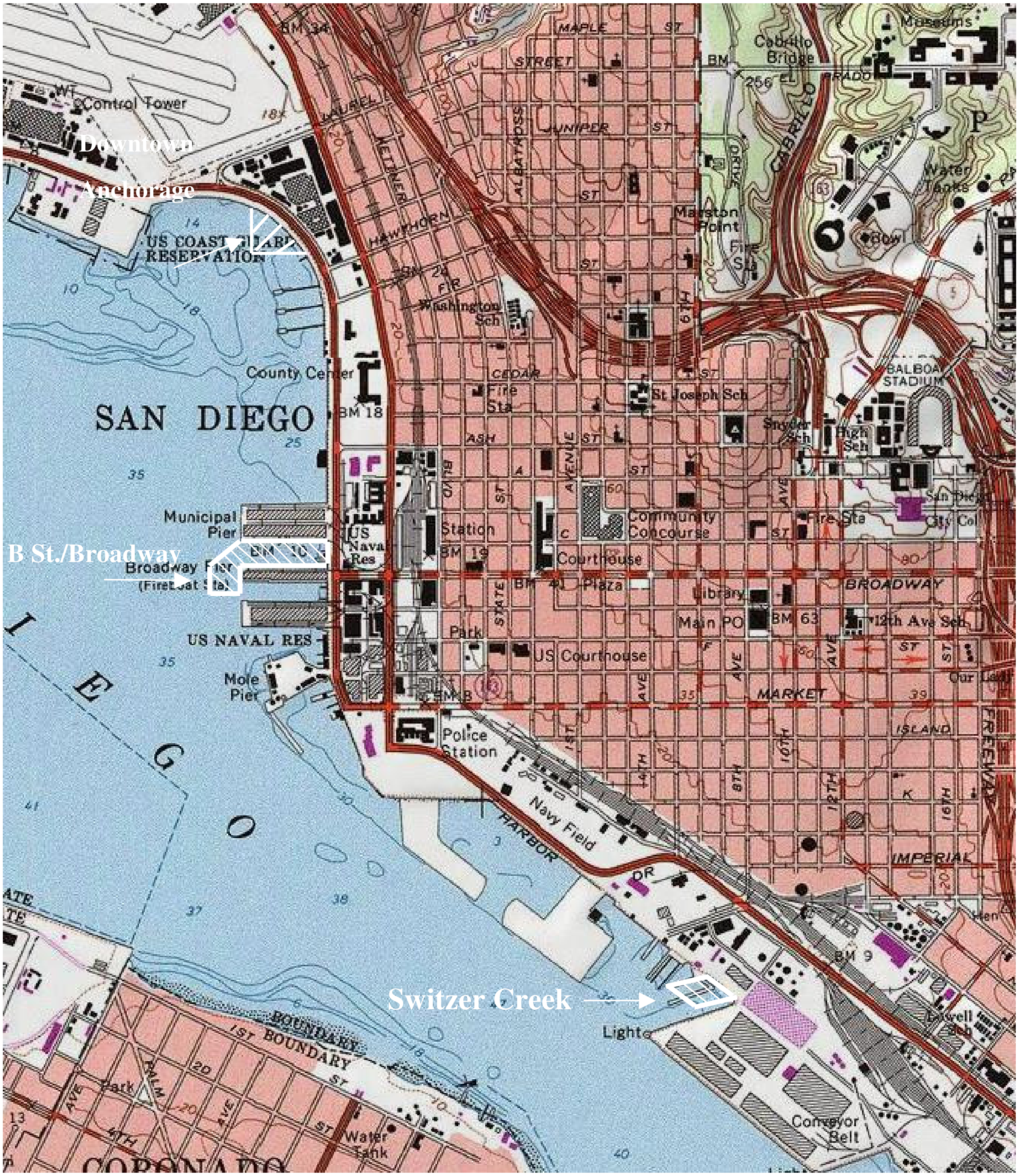


Figure 1-2. Switzer Creek, B Street/Broadway Piers, and Downtown Anchorage study sites (in crosshatch; RWQCB – San Diego).

designated as moderate priority sites. The B Street/BroadwayPiers site was designated on the basis of benthic community degradation, and elevated concentrations of polycyclic aromatic hydrocarbons (PAHs), copper, chlordane, and total chemistry. The Downtown Anchorage area was designated on the basis of metal and organochlorine pesticide contamination, sediment toxicity, and benthic community degradation. The Switzer Creek site was designated on the basis of toxicity, benthic community degradation, and elevated concentrations of copper, PAHs, chlordane and total chemistry (Fairey et al., 1996; Fairey et al., 1998). Historical data for the B Street/Broadway Piers, Downtown Anchorage area, and Switzer Creek sites were compiled from BPTCP reports (Fairey et al., 1996; Fairey et al. 1998), and are summarized in the Phase I SAP (UC Davis – MPSL, May 2002).

2.0 STUDY DESIGN AND METHODS

2.1 OBJECTIVES AND APPROACH

The primary goals of this study were to investigate temporal patterns and chemical causes of impacts on the benthic environment in the vicinity of the B Street/Broadway Piers, Downtown Anchorage, and the area adjacent to the mouth of Switzer Creek. Once chemicals of concern were identified, likely sources of these chemicals were to be identified.

The conceptual approach of the study is based on three key assumptions. First, that the determination of biological impairment is best assessed through the measurement of biological effects associated with the study site (e.g. toxicity, bioaccumulation, and benthic community degradation). Second, multiple indicators of sediment quality must be measured in order to provide a confident assessment of impacts because no single test or parameter is a consistently reliable, accurate, and predictive indicator of impairment. The final assumption is that there may be unknown site-specific factors in the study areas that will significantly affect causal relationships between contamination and effects, thus site-specific information is needed to accurately assess impacts.

This study will build on results of analyses conducted as part of the Phase I Sediment Quality Assessment. In Phase I, multiple measures of sediment quality were conducted at each station to identify the spatial extent of contamination and associated impacts. The Phase II study design entailed the collection of sediment from a subset of stations investigated as part of the Phase I studies.

As in the Phase I studies, we measured four indicators of sediment quality in Phase II: sediment contamination, sediment toxicity, benthic community composition, and bioaccumulation. These four indicators are directly related to the reasons for including these sites on the 303(d) list of impaired water bodies. We also measured other habitat factors that are necessary for the comprehensive interpretation of these indicator data. The use of multiple indicators supports a weight-of-evidence approach that increases the likelihood that the sediment quality at each sampling site will be accurately assessed.

The results of the Phase I spatial studies were used to plan subsequent studies that are needed to support TMDL and cleanup activities at the sites. Spatial distribution of contamination and toxicity were be used to select a subset of stations for toxicity identification evaluations (TIEs) in order to identify contaminants of concern for development of TMDL targets. A subset of the studies identified from the Phase I studies were also selected to determine temporal patterns of contamination and bioeffects as part of Phase II. Determination of the spatial extent of impairment will also facilitate identification of the area requiring remediation, and provide a baseline upon which to assess the effectiveness of load reductions and remediation actions.

2.2 SITE CONCEPTUAL MODEL

Based on existing data, site conceptual models were developed to help clarify the potential linkages between sources, exposure pathways, and receptors. All of the sites share similar characteristics including identified impairment of sediments, stormwater inputs from shoreline sources, and shoreline industrial activities. In addition, the Switzer Creek study area receives considerable upland inputs from the creek itself. Thus, the conceptual models for each study area reflect the generic processes that are expected to be dominant at the sites. The models are broken into two parts, the first illustrating the potential for ongoing sources to impact the site, and the second illustrating the potential exposure pathways for contaminated sediments to reach receptors.

The primary categories of potential ongoing sources are illustrated in Figures 2-1 and 2-2. These include stormwater from the upland watershed that enters the Switzer Creek site via creek drainage, stormwater from the neighboring shipping facilities and shipyards that enters the site primarily via small storm drains, and in-water sources primarily from ships via release from antifouling coatings and zinc cathodic protection systems. A significant fraction of this source material is likely to enter the site in association with particulate matter, or adsorb onto particulate matter at the site. Because of the relatively weak currents in the Switzer Creek study area, it is anticipated that much of the source material that enters the site will deposit to the sediment bed within the site, rather than be transported to the bay. This is the process that is conceptualized in Figure 2-1. In the B Street/Broadway Piers and Downtown Anchorage areas (Figure 2-2), there is greater potential for transport of contaminated sediment from adjoining areas because of tidal eddys in this part of the bay (Fairey et al. 1996). There are also a number of storm drains in the vicinity of the Downtown Anchorage. Additional insight into the links between these sources and the sediment will be gained from supporting and follow-on studies for source quantification and TIE characterization.

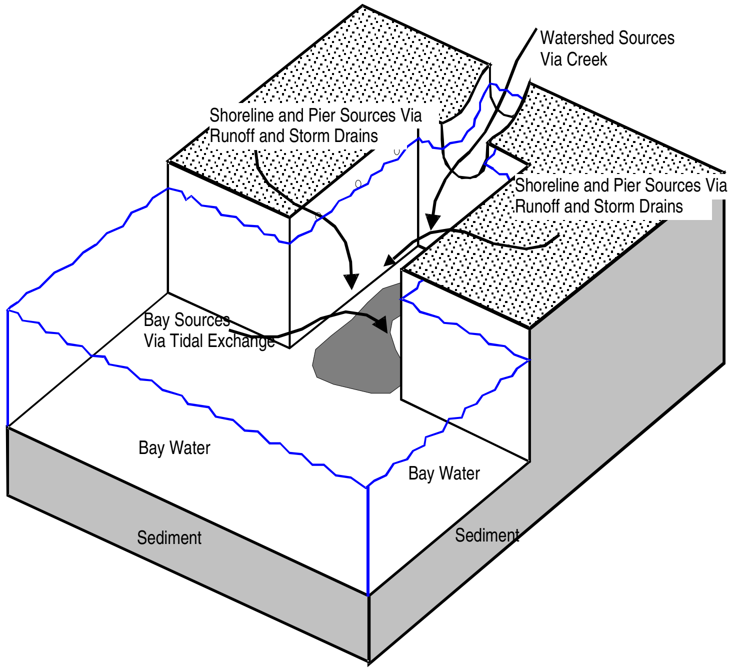


Figure 2-1. Generic site conceptual model for the Switzer Creek study area showing potentialsources and pathways to the sediment.

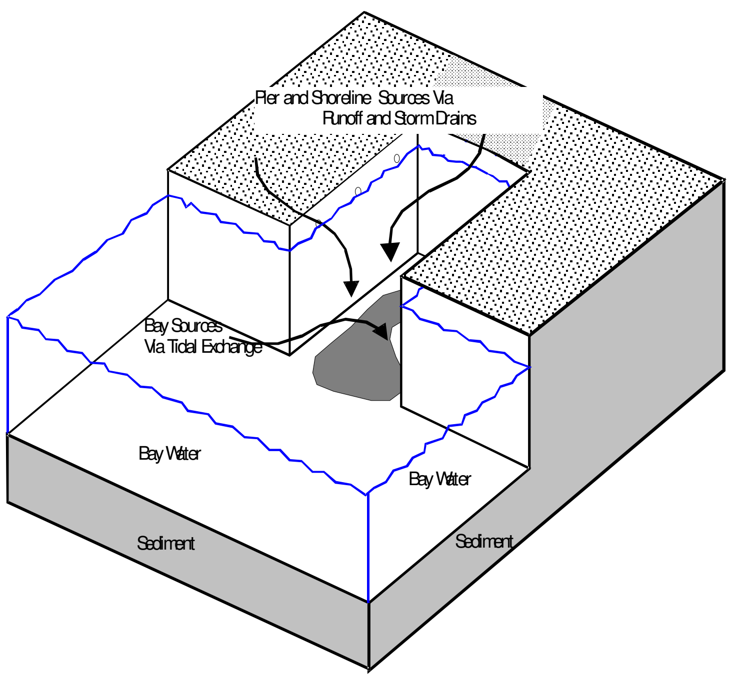


Figure 2-2. Generic site conceptual model for the B Street/Broadway Piers and Downtown Anchorage study areas showing potential sources and pathways to the sediment.

Potential pathways of exposure and receptors are illustrated in Figure 2-3. All of the sites under investigation are intermediate water depth environments. This has important implications for the potential exposure pathways that may exist. For the contaminants in the sediment, one potential ecological exposure pathway is for direct contact or ingestion by benthic infauna, primarily invertebrates such as crustaceans, polychaetes and mollusks (Fairy et al., 1996). In association with this pathway, a second level of ecological exposure may occur for bottom feeding fish that prey on these benthic invertebrates. Existing survey data suggests that in these areas exposure would be primarily to species such as the California Halibut, Round Stingray, and Barred Sand Bass (U.S. Navy/SDUPD, 2000). Because of the depth of the sites, it is unlikely that transfer to fish-eating bird species would occur. Diving birds and surface feeding birds generally limit their activities to shallow water areas, and there are few upper level receptors that feed directly on the bottom fish species mentioned above. It is possible that surf scoters (*Melanitta perspicillata*) or lesser scaup (*Aythya affinis*) feeding on shellfish may be exposed to bioaccumulatable contaminants at these sites, particularly at the Switzer Creek and Downtown Anchorage sites. Potential exposure to humans may occur through fishing activities that involve direct take of those bottom fish. Although fishing activity is generally not common within the direct confines of the sites, the mobility of the fish could provide a complete pathway for fishing activities that occur outside the site at nearby public fishing piers or in the open areas of the bay to the east of the site.

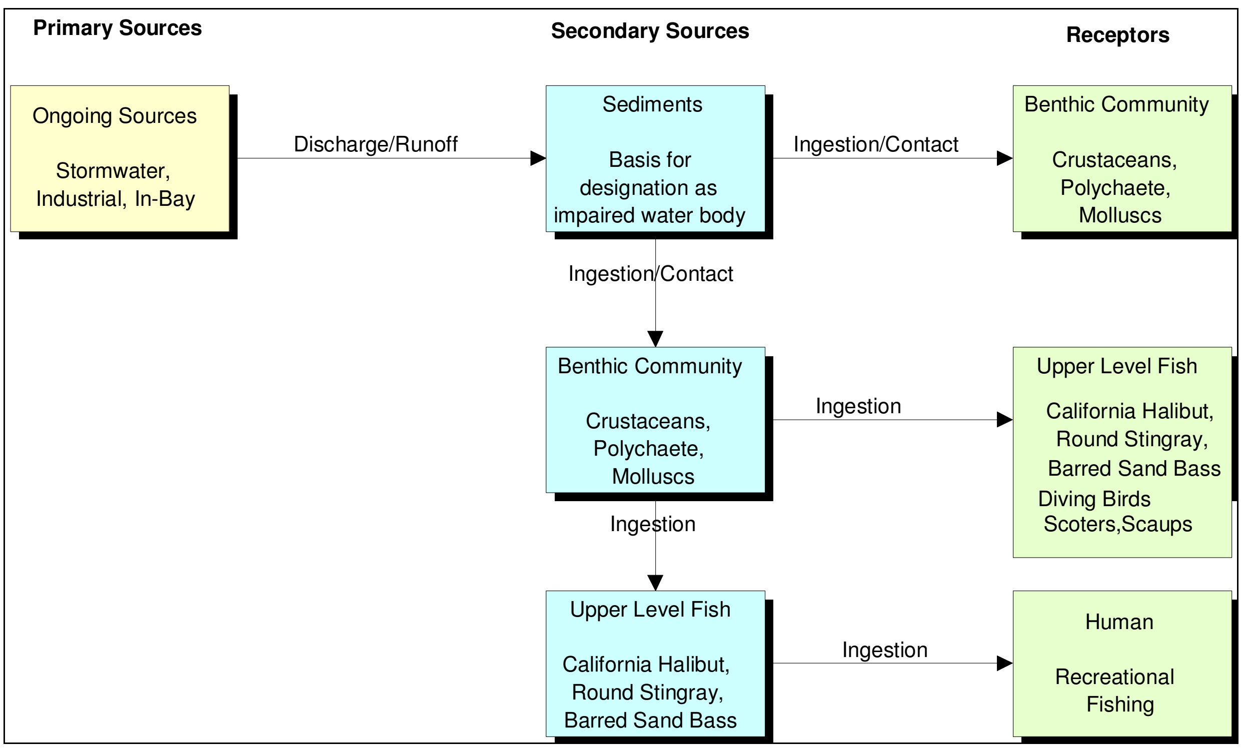


Figure 2-3. Generic site conceptual model for B Street/Broadway Piers. Downtown Anchorage and Switzer Creek showing the relationship between potential sources, pathways of exposure and receptors.

The measurements described in the following sections are designed to evaluate the exposure pathways conceptualized above. The sediment quality indicators were selected to provide quantifiable measurement endpoints to determine if these pathways of exposure are sufficient to drive significant ecological or human health risk.

2.3 SEDIMENT QUALITY INDICATORS

Up to four types of sediment quality indicators, as well as sediment characteristics necessary for indicator data interpretation will be measured at each station. Multiple indicators are necessary to increase the likelihood of an accurate determination of the presence or absence of sediment degradation at each site by supporting a weight of evidence approach to the data analysis. Each indicator is complementary to the others with regard to assessing the presence of an impact and determining whether impacts are related to chemical contamination.

Methods equivalent to those used in the BPTCP and Bight'98 regional surveys will be used wherever there is a choice. This will permit directly comparing results of the present study with region-wide values when evaluating impacts and temporal trends.

2.3.1 Sediment Contamination

Sediment chemical measurements will be used to document the extent, spatial pattern, and relative magnitude of sediment contamination at each study site, assess temporal trends through comparisons to prior measurements, and indicate the potential biological availability of sediment-associated trace metals.

The concentrations in surface sediments of the trace metals and organic contaminants measured in the Bight'98 survey (Appendix 1) will be measured at all sampling sites. The chemical analyses will use methods that are comparable to those used in the Bight'98 survey. Surface sediments are defined as those within 5 cm of the sediment-water interface.

2.3.2 Sediment Toxicity

Sediment toxicity tests will be used to document the extent, spatial pattern, and relative magnitude of acute toxicity and sublethal effects in the sediments at each study site.

Acute toxicity will measure survival of the amphipod crustacean, *Eohaustorius estuarius,* after 10 days of exposure to whole sediment (EPA 1994). Porewater and overlying water in the test chambers will be measured for ammonia; water changes will be performed as needed to reduce ammonia effects.

Sublethal sediment toxicity will be assessed by measuring the effects of porewater on sea urchin fertilization (EPA 1995). Porewater will be extracted from samples of surface sediment by centrifugation and diluted with laboratory seawater to obtain concentrations of 100, 50, and 25%. Sea urchin sperm will be exposed to each sample for 20 minutes and then the toxic effects are evaluated by measuring the ability of the sperm to fertilize eggs.

The possibility of toxicity due to unionized ammonia was assessed by comparing concentrations in the toxicity test containers to existing threshold effect and LC_{50} concentrations established for each species. In addition, concurrent unionized ammonia reference toxicant tests will be conducted with each lot of test organisms to verify tolerance to this constituent.

2.3.3 Toxicity Identification evaluations

Causes of toxicity were investigated in selected solid-phase samples using a weight-of-evidence approach based on comparisons of responses to bulk-phase chemical concentrations, evaluation of sediment physical and non-anthropogenic chemical attributes, and U.S. Environmental Protection Agency toxicity identification evaluations (TIEs). Where appropriate Phase I (characterization) and Phase II (identification) TIEs were conducted to determine causes of toxicity. Samples selected for TIEs were from stations demonstrating the greatest magnitude of toxicity in the Phase II studies.

2.3.4 Benthic Community Composition

The numbers and kinds of benthic invertebrates in sediment samples were used to characterize benthic communities at each study site.

Sediment collected using a $0.1m^2$ Van Veen grab at each sampling site was sieved through a 1.0 mm-mesh screen onto a 0.5 mm screen. Animals retained on both screens analyzed separately were identified to the lowest possible taxon, and enumerated. Most taxa will be identified to species. These data were used to calculate the Benthic Response Index, as well as other metrics such as macroinvertebrate abundance, Shannon-Wiener Diversity, and species richness.

2.3.5 Sediment Characteristics

Sediment characteristics that influence the bioavailability of contaminants, the response of toxicity test organisms, and the structure of benthic communities were measured to distinguish biological impacts (i.e., toxicity or benthic community alteration) due to contaminants from those due to physical or non-anthropogenic factors.

The sediment grain size distribution and total organic carbon content of surface sediments were measured at each station using methods comparable to those used in the Bight'98 regional survey.

2.3.6 Bioaccumulation

Bioaccumulation tests was used to evaluate the potential for contaminant uptake and subsequent food chain transfer of organic chemicals and metals from the sediment. Samples from the B Street/Broadway Piers, Downtown Anchorage area, and Switzer Creek stations were compared to samples from appropriate reference stations to determine whether they pose a significantly greater potential for bioaccumlation. Bioaccumulation tests were conducted at reference stations and a subset of B Street/Broadway Piers, Downtown Anchorage area, and Switzer Creek stations that span the expected gradient of contamination at the site. Clams (*Macoma nasuta*) were tested using the standard laboratory 28-day exposure protocol (USEPA/USACOE 1991), with sufficient number of organisms to provide ~50-100 g of tissue (wet weight) for chemical analysis. Sediments were obtained from composite grabs from the top 5 cm at each station.

All trace metal and organic constituents to be measured in sediment samples were measured in clam tissues after exposure to study-area sediments for 28-days. The data were lipid normalized (where appropriate) and also compared to concentrations in tissue samples collected at the start of the experiment (t0). The test species is native to and widely distributed in San Diego Bay and actively ingests surface sediments. It is commonly used in dredged sediment studies (USEPA/USACOE 1991) because it provides enough tissue for trace level chemical analysis.

2.4 SEDIMENT SAMPLING

Sediments for Phase II studies were collected in February, August, and October 2004. Sample locations for the Phase II studies were based on the results of the Phase I studies. The three stations sampled in the Switzer Creek study area were SWZ01, SWZ02, and SWZ04. The three stations sampled in the B St./Downtown Piers study area were BST01, BST04, BST07. The three stations sampled in the Downtown Anchorage study area were DAC02, DAC03, and DAC04. Based on the weight-of-evidence from the Phase I studies, these were the most highly impacted stations in each study area, and so, were of greatest interest for temporal and TIE studies for Phase II.

Sampling methods were consistent with procedures used in the BPTCP (Fairey et al. 1996) and the Bight'98 surveys; a 0.1 m^2 Van Veen Grab was used for all sediment sampling. Sediment for chemical, toxicity, or bioaccumulation analyses was obtained from the upper 5 cm of the sediment surface. During each deployment of the grab sampler, sediment for toxicity, chemistry and bioaccumulation were collected from both sides of the grab sample. The entire contents of a separate grab sample from the station was processed for benthic community analysis (August 2004, only).

Approximately 4-7 replicate grab samples were taken at each station in order to provide sufficient sediment for all of the analyses, except at the bioaccumulation replicate stations where an additional 6-8 grabs will be required. Surface sediment from multiple grabs was composited together on board ship, mixed to obtain homogeneity. Samples was transported on ice to the clean facility at the Marine Pollution Studies Laboratory (Moss Landing), where they were re-homogenized and then distributed into separate containers for chemistry, toxicity and bioaccumulation testing.

A sufficient number of grab samples will be collected in each study area to determine temporal patterns of contamination and associated bioeffects. To account for temporal variability, all stations will be sampled three times: once during the wet season (February 2004), and twice during the dry season (August and October 2004). These data were compared to the Phase I data collected in the post-wet-season in May/June 2003. Because the majority of non-point source contaminant loadings in Southern California occur during the wet season (Schiff et al., 2001), it is possible that greater contamination and bioeffects will be observed in wet-season sample. Variability between seasons was compared using the wet and dry season samples collected as part of Phases II studies. Together, the four datasets collected as part of the Phase I and II studies are sufficient to describe temporal variability. Variability was assessed in terms of differences in the contaminant concentrations and the relative magnitude of bioeffects, and bioaccumulation. Toxicity, chemistry, sediment physical factors, and bioaccumulation was measured in all samples collected in Phase II. Because benthic community structure is highly influenced by seasonality, this component was measured only in the August 2004 samples in Phase II for comparison to the spring 2003 samples collected as part of the Phase I studies. May through August was selected as an appropriate index period for characterizing benthic community structure in southern California because the majority of invertebrate species recruitment occurs then (J. Oakden, personal communication).

2.4.1 Switzer Creek

The Switzer Creek study area (Figure 2-4) is located between the north side of the 10th Avenue Marine Terminal and the Campbell Shipyard Piers at the mouth of Switzer Creek. The total sediment surface area is approximately 28,000 m^2. Stations SWZ01, SWZ02, and SWZ04 were sampled 3 times (February, August, and October 2004; Fig. 2-4). The exact locations of Switzer Creek stations are listed in Appendix 2.

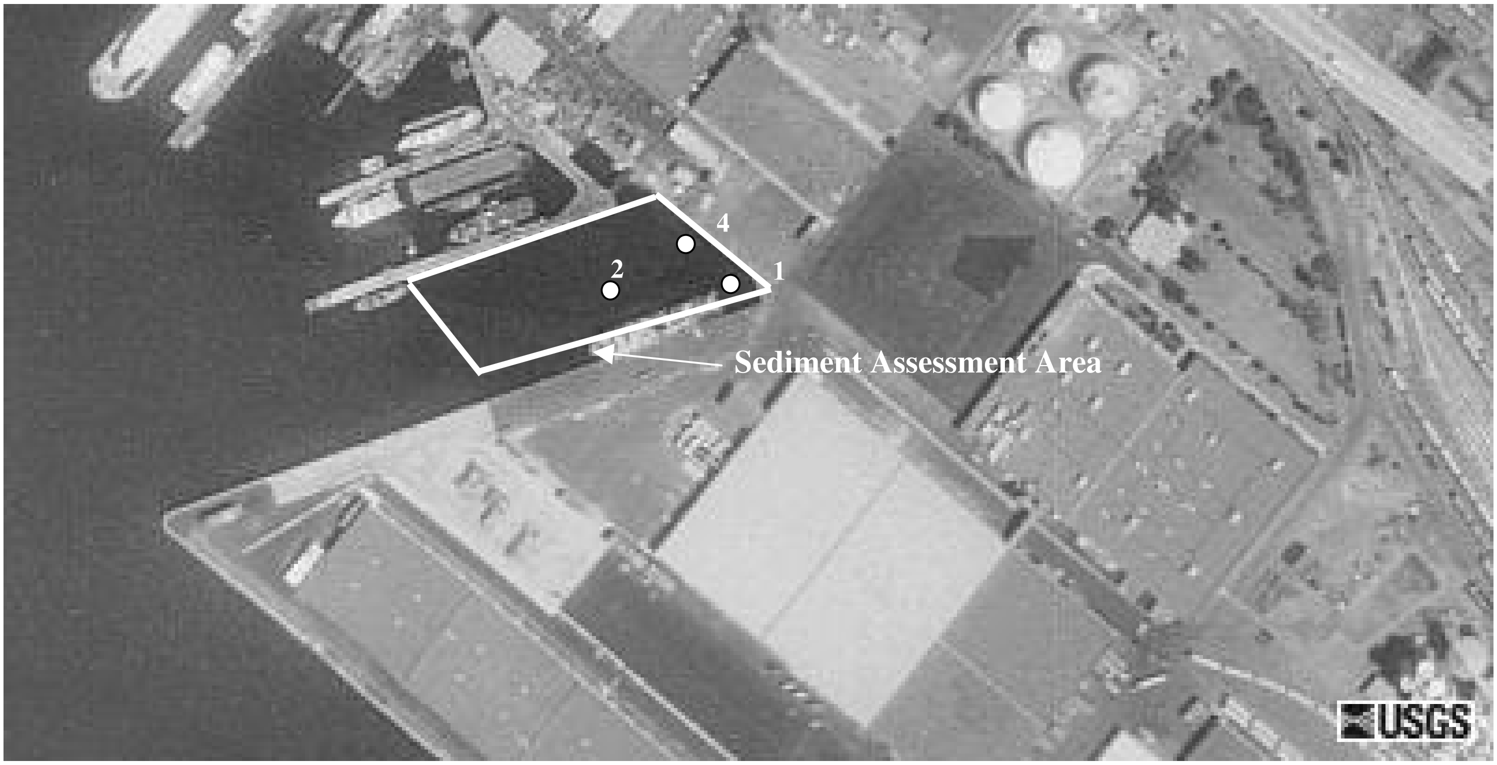


Figure 2-4. Switzer Creek study area with sample locations.

2.4.2 B Street/Broadway Piers

The B Street/Broadway Piers study area is located just south of the Municipal Pier, near the US Navy Reservation, and extends southwest approximately 100 m from the end of the Broadway Pier (Figure 2-5). Total sediment surface area is approximately 48,000 m^2. The 3 sampling stations were selected from those demonstrating the greatest contamination and toxicity based on the Phase I results (BST01. BST04, BST07) Specific locations of the B Street/Broadway Piers stations are summarized in Appendix 2.

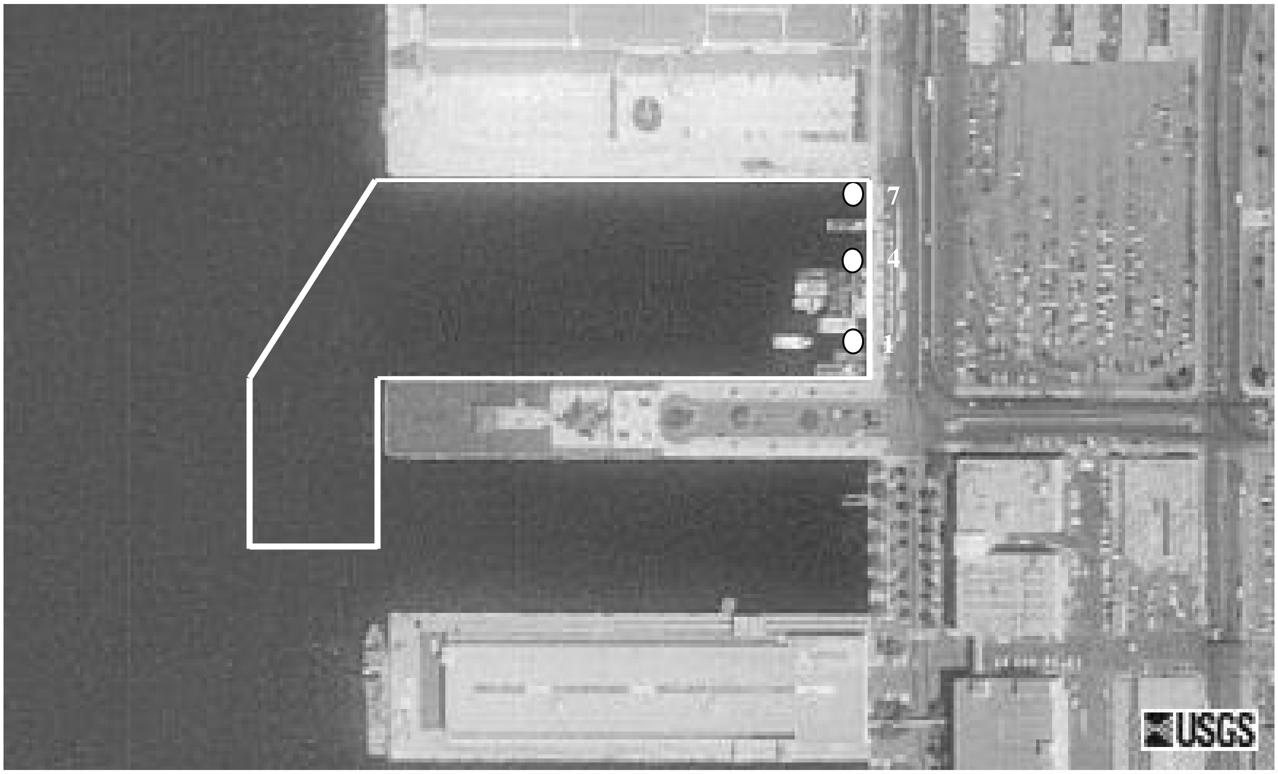


Figure 2-5. B Street/Broadway Piers study area with sample locations.

2.4.3 Downtown Anchorage

The Downtown Anchorage study area is located between Grape Street and Laurel Street in the vicinity of the U.S. Coast Guard Reservation (Figure 2-6). Total sediment surface area is approximately 32,000 m^2. The 3 sampling stations were selected from those demonstrating the greatest contamination and toxicity based on the Phase I results (DAC02, DAC03, DAC04). Specific locations of the Downtown Anchorage area stations are summarized in Appendix 2.

Figure 2-6. Downtown Anchorage study area with sample locations.

2.4.4 Reference Stations

Five of the six reference stations described in the Phase I SAP were used during Phase II. For consistency, these included three of the same reference stations used in the Chollas Creek, Paleta Creek, and NASSCO/Southwest Marine sediment assessment studies. The two additional reference stations were those recommended by the Regional Water Board (Brennan Ott, SD Water Board, personal communication).

The reference stations and some of the characteristics meriting their use are given below.

Station #2433: Relatively high TOC and % fines, located in northern part of bay.

Station #2243: Relatively low TOC and % fines, deep water, near ship traffic.

Station #2238: Relatively low TOC and % fines, located in south part of bay.

Station # 2229: Relatively low TOC and % fines, located in north central part of bay.

Station #2441: Relatively high TOC and % fines, located in north part of bay.

Table 2-1. Characteristics of reference sites for San Diego Bay. The characteristics of the B Street/Broadway Piers, Downtown Anchorage area, and Switzer Creek study sites and NPDES reference sites are also shown. Shading indicates recommended reference stations.

Station/ Area	Level	% Fines	TOC	Cu mg/kg	Zn mg/kg	PAH μg/kg	ERMq	# Species
Switzer		24-75	0.2-2.2					
B St/Broadway Piers		48-62	1.2-2.2					
Downtown Anchorage		36-86	0.9-1.9					
REF-01		38		16.6	49.4	902		
REF-02		42		179	226	72		
REF-03		65		99.1	159	5957		
2227	1	50	0.9	53.9	112	324	0.12	52
2435	1	49	0.5	28.4	64.4	0	0.07	59
2229	1	43	0.9	58.9	99.3	970	0.12	62
2440	1	38	0.5	41.8	81.1	0	0.09	58
2231	1	31	0.6	58.1	92.5	258	0.10	70
2441	2	79	2.0	71.8	123	1061	0.13	84
2225	2	57	1.0	127	130	146	0.19	69
2433	2	71	1.2	71.6	126	240	0.14	58
2442	2	79	2.0	77.7	139	4950	0.14	52
2238	2	57	1.0	55.1	143	0	0.12	41
2243	3	35	0.5	38.8	81.2	0	0.09	47
2240	3	44	0.5	47.4	103	85	0.11	40

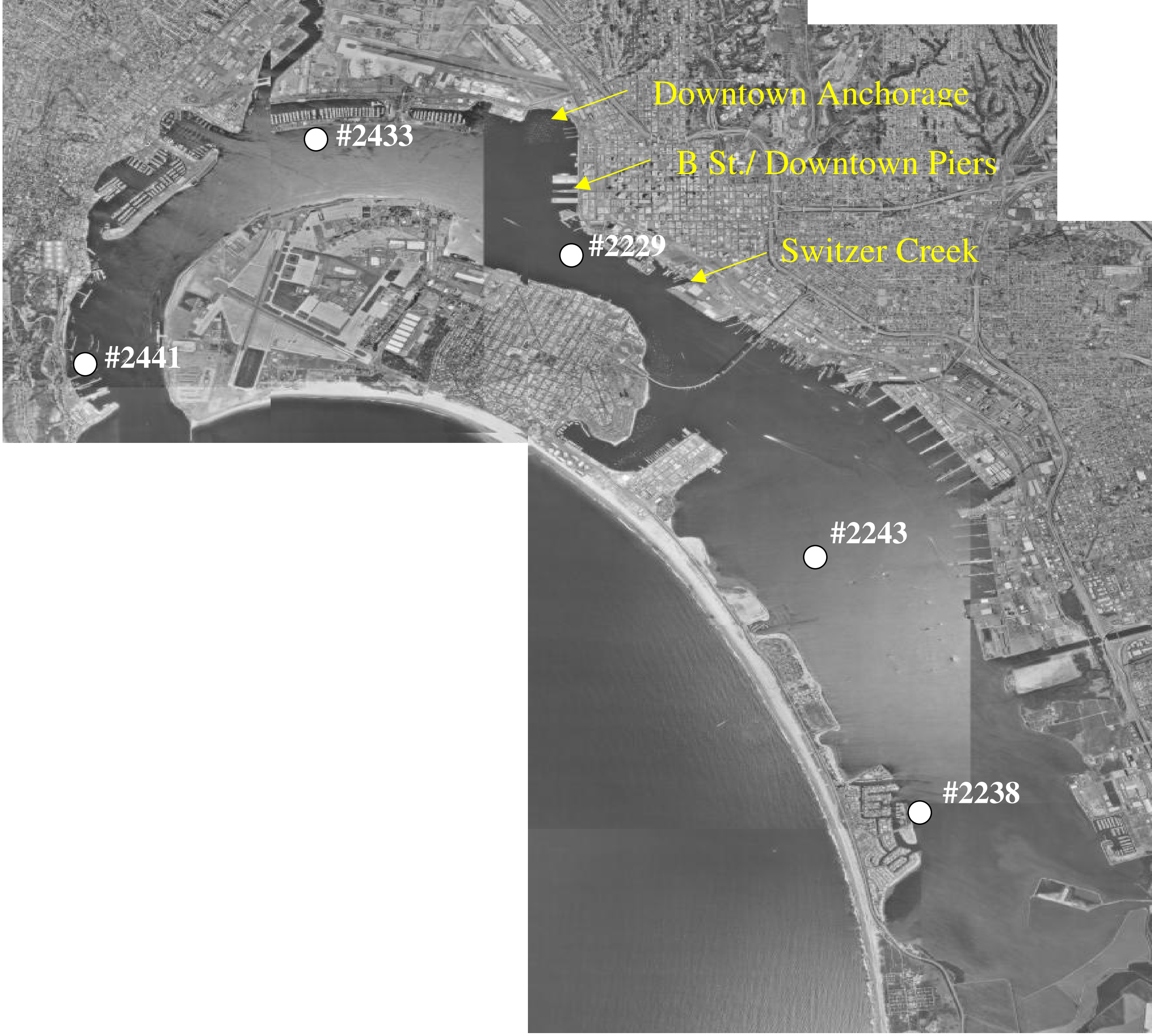


Figure 2-7. Location of candidate reference sites in San Diego Bay.

2.4.4 TOXICITY IDENTIFICATION EVALUATIONS (TIEs)

Toxicity Identification Evaluations (TIEs) are laboratory experiments that incorporate various treatments designed to reduce toxicity of water and sediment samples. The treatments are designed to mitigate toxicity caused by specific classess of chemicals such as non-polar organic compounds, divalent cations, and ionizable contaminants. Results of these experiments provide information on chemical causes of toxicity. TIEs are designed to proceed in three phases: Phase I procedures characterize the chemicals responsible for toxicity; Phase II procedures identify the cause(s) of toxicity; Phase III confirm the cause(s) of toxicity. In the current study, Phase I, and where possible, Phase

II TIEs were conducted on samples from selected sites exhibiting significant toxicity. For sites exhibiting solid-phase toxicity to amphipods, follow-up 10-day porewater and solid-phase experiments were conducted to determine the likely route of toxicant exposure. TIEs with amphipods were conducted using solid-phase, and sediment elutriate samples. This approach is detailed as a TIE decision tree in schematic form in Appendix 7. In all cases, TIEs were used in conjunction with physical and chemical analyses of different sediment matrices, and correlation analyses of relations between chemistry and toxicity, as part of a weight-of-evidence approach.

2.4.5 Amphipod TIEs

Amphipod TIEs were conducted using sediment collected in February 2004 from Switzer Creek SWZ01 and Downtown Anchorage DAC04. The general approach for amphipod TIEs followed Appendix I.

2.5 CONTAMINANT SOURCE IDENTIFICATION

Once the chemicals of concern (COCs) were identified, the sources of these contaminants were investigated. In this study, COCs were defined as chemicals responsible for toxicity, or chemicals identified as those detrimental to ecological or human health due to their bioaccumulation from sediments. Appropriate mitigation measures can only be implemented in the TMDL process after the primary contamination sources are identified. Source identification involved several lines-of-evidence, including an analysis of historical data, a spatial assessment of current data, and proximity of likely sources of contaminants.

Historical data relevant for the three study areas were reviewed to assess spatial trends in distributions of contaminants of concern and associated bioeffects. Emphasis was placed on analysis of Bay Protection and Toxic Cleanup Program (BPTCP) and Bight 1998 data sets. Where appropriate, data collected as part of previous Regional Board studies, or ongoing Port dredging studies was also considered. Spatial analysis of historic data was compared to current Phase I and II data to investigate likely sources of contaminants identified through the TIE process, or through bioaccumulation studies.

3.0 DATA ANALYSIS AND INTERPRETATION

Analysis and interpretation of the results will consist of 4 activities: evaluation of data quality, determination of impacts for each indicator, assessment of impairment at each station, evaluation of temporal contamination and bioeffects patterns, and determination of causes of toxicity. The procedures used to accomplish each of these activities are described below.

3.1 DATA QUALITY EVALUATION

Upon completion of testing, the data from each indicator will be compared to predetermined objectives for data quality. These objectives include parameters such as control performance for toxicity tests, accuracy and precision for sediment and tissue chemical analyses, and sorting efficiency and identification accuracy for benthic analysis. The objectives used in this study will be those specified in the Bight'98 quality assurance plan (chemistry, toxicity, and benthos) or in the standard method used for the bioaccumulation tests. Measurements failing to meet data quality objectives will be repeated wherever possible. Reanalysis may not be possible in some cases due to limited sample or holding time constraints. In these cases, the data will be evaluated by a supervising analyst and their best professional judgment used to determine the validity of the data. Data failing to meet all quality objectives will be flagged in the database produced from this study.

3.2 DETERMINATION OF IMPACTS

3.2.1 Aquatic Life Impact

The sediment triad approach to assessing aquatic life impact relied on the three principal LOE that included measures of sediment chemistry, sediment or interstitial water toxicity, and benthic community composition. The three LOE were individually evaluated to determine the presence of significant impacts at each station by using a three-step process. First, the data quality of each LOE was assessed relative to predetermined objectives such as accuracy and precision for sediment and tissue chemical analyses, control performance and confounding factors in the toxicity tests, and sorting efficiency and identification accuracy for the benthic analyses. Second, the data were compared to published thresholds, guidelines, or controls that indicate whether a significant response was obtained. Finally, the data were compared to the study baseline condition to assess the site-specific impact. This approach is based on the framework for evaluating sediment quality developed by the EPA for application in the St. Louis River Area of Concern (USEPA, 2000). The degree of impact indicated by each LOE was then be integrated into a weight of evidence (WOE) evaluation to provide an overall assessment of potential for aquatic life impairment (USEPA, 1997).

3.2.1.1 Sediment Chemistry

Bulk sediment chemical concentrations measured at each station were evaluated relative to sediment quality guidelines (SQGs) as well as to the reference condition. SQGs have been established as one of the most effective methods for attempting to relate sediment chemistry to their observed toxic effects (Long et al., 1995; Long et al., 1998). The evaluation in this study compared CoPCs relative to their individual ERM for metals (effects range-median, Long et al., 1995), consensus midrange effects concentration for PAHs and PCBs (MacDonald et al., 2000: Swartz 1999), PEL for chlordane (probable effects level, MacDonald et al., 1996), and organic carbon normalized DDT effects value (Swartz et al., 1998) and their respective 95 percentile predictive limit calculated from the Baseline Pool data. The magnitude of impact was addressed by counting the number of CoPCs that exceeded each of their individual benchmarks, by evaluating them as a group against a mean SQGQ1 quotient benchmark (Fairey et al. 2001), and by counting the number or parameters that exceeded the reference condition predictive limit.

The relative magnitude of potential site-specific impact from bulk sediment CoPCs was classified into three ordinal ranking categories of low, moderate, or high likelihood of impact. The ranking was based on a semi-quantitative measure that give increasing weight to a greater number and magnitude of chemicals exceeding a threshold, similar to the method used by Long et al. (1998). The breakpoints in the ranking levels were established using best professional judgment (BPJ), again, following Long et al. (1998). The ranking criteria were based on two key assumptions. First, that there is a low likelihood of impact from CoPCs if all chemicals at a station are less than relatively low SQGs and less than the established reference condition. Second, that there was a high likelihood of impact from CoPCs when many of the chemicals at a station exceed a relatively high SQG, and exceed the reference condition. The category ranking criteria for bulk sediment chemistry are summarized below.

Low- The mean SQGQ1 was less than 0.25 or all chemicals were less than the 95% predictive limit calculated from the reference condition. Additionally, there must not be any single chemical that exceeded either its SQG or reference condition predictive limit value whichever was higher. To meet this category, all chemicals present at the site, either individually or summed must have been lower than a relatively low SQG and have been below the reference condition.

Moderate- The mean SQGQ1 was between 0.25 and 1.0 and greater than the 95% predictive limit calculated from the reference condition. Additionally, a station was classified into this category if there were five or less individual chemicals that exceeded their respective SQG or reference condition predictive limit, whichever was higher. To meet this category, some (five or less) chemicals either individually or when summed exceeded a moderate level SQG and/or the reference condition.

High- The mean SQGQ1 for all chemicals was greater than or equal to 1.0 and was greater than the 95% predictive limit calculated from the reference condition data. This category was also assigned if more than five chemicals exceed their individual SQG or the reference condition, whichever was higher. To meet this category, the reference condition as well as a relatively high SQG must have been exceeded when chemicals are considered as a group, or that there were at least six individual chemicals exceeding a SQG or the reference condition.

3.2.2.2 Sediment Toxicity

The two toxicity test results were compared to their negative controls (collection site sediment or laboratory seawater) as well as to the 95% lower prediction limit calculated from the reference stations to determine the relative magnitude of station toxicity for this LOE. The magnitude and consistency of responses was used to classify station sediments as having a low, moderate, or high degree of toxic effects. The rankings were based on the combined toxic response from both tests.

Similar to the chemistry LOE, the ranking method employed a semi-quantitative assessment of the data that reflected both the presence and magnitude of toxicity. It was assumed that there was no, or a low degree of, toxic effects if the results of both toxicity tests were not significantly different from their controls or they had a statistically lower level of toxicity than observed under the baseline condition. Each of the toxicity tests was given equal weight for classifying a sample as moderately toxic; the presence of significant toxicity in any one test was sufficient to classify a sample as moderately toxic. A high degree of sediment toxicity was indicated when survival of amphipods was less than 50% and significantly different from the control and baseline. A high toxicity ranking was also assigned when both of the tests measured a greater level of toxicity than the baseline condition.

The amphipod test result was given greater weight for the high toxicity category because the acute survival endpoint of this test was assumed to have a higher degree of association with ecological impacts than the sublethal tests. The sea urchin fertilization test results was given less weight because this is a sublethal critical life stage tests that is more susceptible to confounding factors and its association with ecological impacts is less certain. The category ranking criteria for sediment toxicity are summarized below.

Low- There were no or a low degree of toxic effects if results of both bioassays were not significantly different from their controls or they had a statistically lower level of toxicity than observed under the reference condition.

Moderate- The sediments were considered moderately toxic if either one of the bioassay results was statistically different from its control and was less than the reference condition. There was an additional requirement that amphipod survival must have been greater than 50%, regardless of the result relative to controls or reference.

High- There were multiple criteria that can result in a categorization of the sediments as having a high degree of toxicity: 1) If survival of amphipods at a station was less than 50% and was statistically different than controls and statistically less than baseline. 2) If the amphipod test together with the fertilization test both had a result that was statistically different from control and was statistically less than reference condition.

3.2.2.3 Benthic Community Composition

Four metrics were used to assess community health at each station: total abundance, total number of species, the Shannon-Wiener (SW) Diversity Index, and the Benthic Response Index (BRI) developed by SCCWRP (Ranasinghe et al., 2003). The Benthic Community LOE compared station data against the Bight'98 BRI response level benchmarks as well as to the 95% lower (upper for BRI) prediction limit of each of the metrics calculated for the Baseline Pool. Consideration was given first to the overall BRI ranking and then to the individual metrics. The BRI was given this higher weighting because it is a more comprehensive measure of community health.

Similar to the other LOE, this evaluation was based on a semi-quantitative measure that integrated the responses and the application of ranking criteria based on BPJ. It was assumed that no, or a low degree of benthic community degradation is present when the station BRI is level I (< response II) or is statistically similar to the baseline condition and abundance, number of taxa and the SW Diversity Index are all statistically similar to the baseline condition. Conversely, a high degree of impact to community health at a station is assumed to be present when there is a BRI response of level IV (> response III) or the other indicators also show impacts. The category ranking criteria for benthic community impacts are summarized below.

Low- Benthic community health at a station had no or a low degree of degradation if the BRI is less than response level II and when abundance, number of taxa, and the SW Diversity Index were all statistically similar to the reference condition.

Moderate- There was a moderate degree of impact to community health at a station if the BRI was either response level II or III and was statistically greater than the baseline condition or if any one of the other benthic community metrics was statistically lower than the reference condition.

High- There was a high degree of impact to benthic community health at a station if the BRI was greater than response level III or the BRI response was greater than level II, statistically greater than the reference condition, and at least one of the other benthic community metrics was also statistically less than reference.

3.2.3 Triad Analysis of Impairment to Aquatic Life Beneficial Use

The three LOE described above were integrated into an overall WOE assessment focused on identifying the likelihood that site-specific aquatic life beneficial use is impaired at a given station due to the presence of a known CoPC related to the site. The approach follows the general principles of WOE analysis described by Chapman (1990, 1996) and others. Potential combinations of the ordinal rankings for individual LOE were assessed and assigned a relative overall likelihood of impairment using three categories “Unlikely”, “Possible”, and “Likely” based on consideration of four key elements as described by Menzie et al., (1996):

- the level of confidence or weight given to the individual LOE
- whether the LOE indicates there is an effect
- the magnitude or consistency of the effect
- the concurrence among the various LOE

For example, a station with a high ordinal ranking for chemistry, toxicity and benthic community would indicate a high likelihood of site-specific aquatic life impairment because each LOE indicates an effect, the magnitude of the effect is consistently high, and there is clear concurrence among the LOE. Alternatively, a station with a low ordinal ranking for chemistry, and moderate or high rankings for toxicity and benthic community would indicate unlikely site-specific aquatic life impairment from site CoPCs, because there is no concurrence with site CoPCs. This does not mean that there is no impairment, but that the impairment is not clearly linked to site related contamination. The framework shown in Table 4-1 was used to interpret the results and is consistent with other published WOE frameworks.

Table 3-1. Weight of evidence analysis framework for the aquatic life impairment assessment. For each LOE (chemistry, toxicity and benthic community), the symbols indicate the degree of impact including low (○), moderate (⊙), or high (●).

Aquatic Life Impairment Table			
Chemistry	Toxicity	Benthic Community	Site-specific Impairment from CoPCs
●	●	●	Likely impairment from CoPCs
●	●	⊙	
●	⊙	●	
⊙	●	●	
●	●	○	
●	○	●	
●	⊙	⊙	
⊙	●	⊙	
⊙	⊙	●	
⊙	⊙	⊙	
●	⊙	○	
●	○	⊙	
⊙	●	○	Possible Impairment from CoPCs
⊙	○	●	
⊙	⊙	○	
⊙	○	⊙	
●	○	○	
○	●	●	Unlikely impairment from CoPCs
○	●	⊙	
○	⊙	●	
○	⊙	⊙	
○	○	●	
○	●	○	
○	○	⊙	
○	⊙	○	
⊙	○	○	
○	○	○	

3.2.4 Aquatic-Dependent Wildlife Impairment

A screening level risk assessment was performed to assess potential impairment to aquatic-dependent wildlife. For this assessment, bioaccumulation of CoPCs in the clam *Macoma nasuta* exposed to site sediments was used to estimate exposure for representative wildlife receptors including surface feeding birds and marine mammals. For the screening level assessment, conservative exposure assumptions included 100% dietary fraction from the site, 100% area use factor for the site, and the low toxicity reference value. The screening level risk assessment for aquatic-dependent wildlife was based on the following procedure. First, chemical concentrations in clam tissue were compared to measurements made on control samples to detect the presence of contaminant bioaccumulation. For those stations with chemicals demonstrating bioaccumulation, clam tissue concentrations were used to estimate contaminant doses to diving birds (lesser Scaup). This receptor is common to San Diego Bay (U.S. Navy/SDUPD, 2000) and provides an ecologically relevant exposure pathway and sensitivity to the CoPCs at the sites. For chemicals with doses exceeding the Toxicity Reference Values (TRV), tissue concentrations of clams exposed to study site sediments were compared with the 95% upper predictive interval of tissue concentrations from the reference stations.

Because the evaluation of aquatic-dependent wildlife is a conservative screening level assessment, sites or stations were assigned a relative likelihood of impairment ranging only from "unlikely" to "possible". The category ranking criteria for site-specific aquatic-dependent wildlife impairment is summarized below. Note that within these classifications, the presence of risk (Hazard Quotient (HQ)>1) does not necessarily equate with site-specific aquatic dependent wildlife impairment, because impairment is also measured relative to the reference condition.

Unlikely - Impairment to wildlife from the consumption of aquatic prey exposed to site sediments is unlikely for a CoPC if: (1) the estimated HQ is less than 1 or (2) the bioaccumulation is not statistically different from the reference condition.

Possible - Impairment to wildlife from the consumption of aquatic prey exposed to site sediments is possible for a CoPC if: (1) the estimated HQ is greater than 1 and (2) there is statistically different bioaccumulation relative to the reference condition.

3.3 SPATIAL AND TEMPORAL PATTERNS OF CONTAMINATION AND BIOEFFECTS

Data of concentrations of selected contaminants, results of toxicity tests and benthic community characterizations, and results of bioaccumulation studies from the Phase I were used to help identify sources of contaminants responsible for observed impacts. Temporal patterns in contamination and bioeffects were assessed by graphical analyses of results over time at the substations from Phase I and Phase II.

4.0 RESULTS

4.1 DATA QUALITY EVALUATION

This section summarizes quality assurance data; except where noted, all quality assurance data are presented in electronic files appended to this report. All analyses were conducted by the same personnel participating in the Phase I studies, except for benthic community taxonomy. Sampling, sample processing, and distribution of samples was conducted by Russell Fairey and Marco Sigala, Moss Landing Marine Laboratories. Sediment and clam tissue chemical analyses and TOC analysis were conducted byRich Gossett, CRG Laboratories. Grain size analysis and *Macoma* bioaccumulation exposure tests were conducted by Barry Snyder and Chris Stransky, AMEC Laboratories. Benthic community analyses were conducted by Doug Diener, Weston Solutions Laboratories. Toxicity tests were conducted by Brian Anderson and Bryn Phillips, UC Davis, Marine Pollution Studies Laboratory.

4.1.1 Sample Handling

All sample collection, handling, preparation and transport occurred as specified in the QAPP (Marine Pollution Studies Laboratory 2003b). Samples were received intact and cool at all analytical and testing laboratories.

4.1.2 Sediment Chemistry and Characteristics

4.1.2.1 Metals

Procedural blanks in deionized water yielded non-detect values for all metal analytes. Matrix spikes in sediment samples were performed for all analytes; all were within acceptable range, and all RPDs for matrix spike duplicates were less than 25%.

4.1.2.2 Organics

Procedural blanks in deionized water yielded non-detect values for all organic analytes during all three sampling periods. Surrogate recoveries were measured in sediment samples; recoveries for the following surrogates were below acceptable recovery thresholds in February 2004 samples: 30% recovery PCB 30 in BST04; 32% recovery of PCB 30 in BST07; 32% recovery of TCMX in BST07; 30% recovery of PCB 198 in DAC03 and DAC04, respectively; 22% recovery of d8 napthalene in reference station sample 2433; 17% recovery of d8 napthalene in reference station sample 2441; 29% recovery of d8 napthalene in sample BST01; 28% recovery of d8 napthalene in sample BST04; 25% recovery of d8 Napthalene in sample BST07; 24% recovery of d10 acenapthene in station 2441 sample; 27% recovery of d10 phenanthrene in station 2441 sample; 37% recovery of d10 acenaphthene in DAC03 sample; 36% recovery of d8 napthalene in DAC02 sample; 21% recovery of d8 napthalene in station DAC03 sample; 38% recovery of d8 napthalene in station SWZ04 sample. All other organic chemical surrogate recoveries were within acceptable ranges in all samples in February, August, and October 2004.

4.1.2.3 Total organic carbon

No quality assurance data were provided with TOC measurements.

4.1.2.4 Grain size

No quality assurance data were provided with grain size measurements.

4.1.2.5 Toxicity Testing

Sample receiving and storage conditions were acceptable. Bulk-phase sediments were refrigerated for ten days prior to testing with *Eohaustorius*. Porewater was extracted from bulk-phase sediments after six days of refrigeration, and refrigerated for two days prior to testing.

Test acceptability criteria were met for all organisms. Water quality parameters measured during tests were within acceptable limits, with the exception of salinity in the *Eohaustorius* tests; most samples were 1 to 2 parts per thousand above the recommended salinity range for the test, but all were well within the salinity tolerance range of the organism. Temperature was within ± 2° C for all tests. Negative control performance was acceptable in all tests.

Copper chloride reference toxicant tests were conducted as positive controls for toxicity tests, and these were within control chart limits. Ammonia toxicity tests were conducted concurrently with the definitive tests, in order to determine ammonia sensitivity for these batches of organisms. Ammonia test concentrations (as NH_3) were selected to bracket published effects thresholds for unionized ammonia.

4.1.3 Benthic Sorting

Sorting and identification of benthic infauna were as outlined in the Bight '98 QAPP.

4.1.4 Bioaccumulation Testing

Macoma exhibited acceptable control survival after 28 days, ranging from 71 to 100% among the three replicates in all three sample periods. Mean temperature, dissolved oxygen, and salinity values met the water quality criteria for all samples tested. On a few occasions, temperature and dissolved oxygen fell outside of their acceptable ranges. When this occurred, flow rates and aeration were immediately corrected. Transient temperature spikes of 2 to 3 hours duration occur on rare occasions, when new test water is added to the system. For these test batches, temperatures quickly returned to the specified test temperature.

4.1.5 Tissue Chemistry

4.1.5.1 Metals

Procedural blanks in deionized water yielded non-detect values for all metal analytes. Matrix spikes in tissue samples were performed for all analytes; all were within acceptable range, and all RPDs for matrix spike duplicates were less than 25%.

4.1.5.2 Organics

Procedural blanks in deionized water yielded non-detect values for all organic analytes. Surrogate recoveries were measured in tissue and in procedural blanks; all were within acceptable range. Matrix spikes in tissue samples were performed for selected analytes; all were within acceptable range.

4.1.5.3 Lipids

Lipids were non-detectable in procedural blanks with deionized water.

4.2 DETERMINATION OF IMPACTS

4.2.1 Sediment Contamination

Concentrations of contaminants were highest in samples collected in February 2004 (Table 4-1), and all samples categorized as having high sediment contamination based on the LOE criteria were collected during this time.

The majority of contaminants included in the analyte list were below the method detection limit in reference station samples during the three sampling periods. No PCBs or pesticides were detected in any reference station samples at any time. All metals and some PAHs were detected in reference station samples, but all were below SQG values in all of the sampling periods. The highest concentrations of contaminants were measured in reference station 2441, and this station had higher concentrations of contaminant mixtures than the other stations. While the SQGQ1 value often exceeded the lower threshold for contamination defined for the LOE categorization (0.25) at some reference stations, none of the samples at any of the reference stations were greater than their respective SQGQ1 95% UPLs. All reference stations were therefore categorized as having low sediment contamination at all times based on the chemistry LOE (Table 4-1).

Relatively low concentrations of PCBs were detected in sediments from all Switzer Creek stations except at SWZ 01 in February 2004. This was the only Switzer Creek sample that exceeded the consensus based total PCBs guideline (CBGV) value and the 95% UPL (Table 4-1). No samples from the B Street/Downtown Piers stations exceeded the consensus based Total PCBs guideline value during any of the sampling periods. One sample from a Downtown Anchorage stations exceeded the PCBs CBGV and 95% UPL; the concentration of total PCBs at DAC03 in February 2004 was 968.7 ng/g. Total PCBs in all other Downtown Anchorage stations were well below the CBG value during the other sampling periods.

Except for chlordanes, few pesticides were detected in these samples. Concentrations of DDTs were below detection limits in all samples at all times, and thus, were not compared to guideline values. Relatively high chlordane concentrations were measured in many samples, particularly in those from the Switzer Creek stations. Highest chlordane concentrations were measured at Switzer Creek in February 2004, and concentrations from all three stations were well above the PEL (4.77 ng/g), and the 95% UPL (Table 4-1). Chordane in SWZ01 in February 2004 was 80.2 ng/g, approximately 17 times the PEL value. Chlordane concentrations also exceeded the PEL and 95% UPL at all Switzer Creek stations in August and October 2004, except SWZ02 in October 2004. Chlordanes and all other pesticides were below the method detection limits in all

B Street/Downtown Pier stations at all sampling periods. Chlordane concentrations exceeded the PEL at the Downtown Anchorage station DAC04 during all three sampling periods. No other pesticides were detected in samples from the Downtown Anchorage at any time.

Although PAHs were detected in the majority of samples, concentrations of total PAHs were generally low relative to the consensus-based guideline value of 1800 µg/g oc dry wt. in all samples at all times (Table 4-1). As with the other contaminants, highest PAHs were measured in the February 2004 samples at all stations. Highest total PAHs were measured in the B Street/Downtown Piers station BST07 in February 2004 (1005.18 µg/g oc dry wt), and although total PAHs were elevated at this station on all three sample events, none of these samples exceeded the CBGV. At Switzer Creek, the highest total PAHs were measured in SWZ01 sediments sampled in February 2004, and concentrations of PAHs in all Switzer Creek sediments declined considerably in the later sampling events. At the Downtown Anchorage, the highest total PAHs were measured in DAC03 sediments sampled in February, and lower concentrations of PAHs were measured in Downtown Anchorage stations in the later sampling events.

With few exceptions, all metals were detected at all stations (Appendix A), and seasonal differences in metal concentrations were less striking than those for organic chemicals. While many metals exceeded the threshold for enrichment based on the baseline pool reference conditions (SCCWRP, 2004), few metals exceeded both their baseline pool thresholds and ERM guideline values (Table 4-1). Zinc was the only metal in Switzer Creek stations SWZ02 and SWZ04 that exceeded both the ERM value and baseline pool threshold in the February sample period. No metals exceeded their ERM values at Swizter Creek in August. Zinc and mercury exceeded their ERMs and baseline pool thresholds at SWZ02 in October. Copper exceeded the ERM and baseline pool threshold at SWZ04 in October 2004 (Table 4-1). Two metals, zinc and copper, exceeded their ERMs and baseline pool thresholds in B Street/Downtwon Piers station BST01 in February 2004. The copper concentration in this sample was 2,960 mg/kg dry wt., which is approximately 11 times the ERM value for this metal. Sediment copper concentrations in the August and October 2004 samples from BST01were comparable to the other values measured in this study, and of the other metals, only mercury exceeded it's ERM value in the other B Street/Downtown Anchorage sediment samples (Table 4-1). Few metals exceeded their ERM values in Downtown Anchorage sediments. Mercury exceeded both the ERM and baseline pool thresholds in samples from all Downtown Anchorage stations in August 2004, and silver exceeded both the ERM and baseline pool threshold in DAC03 sediments during this time. No other metal ERM was exceeded in the February or October 2004 samples from any of the Downtown Anchorage stations.

Potential impacts of contaminant mixtures were calculated using the sediment quality guideline quotient value SQGQ1 (Fairey et al., 2001). SQGQ1 values in all but the reference station sediments exceeded the 95% UPLs for SQGQ1 at all times. Because few individual guidelines were exceeded in this study, sediments that were classified as being highly contaminated based on the LOE for sediment chemistry were placed in this category due to SQGQ1 values greater than 1.0. The highest SQGQ1 values occurred in the February samples, particularly in Switzer Creek sediments. SQGQ1 values at SWZ01 and SWZ02 were 2.055 and 1.734, respectively, and these stations were therefore characterized as having high sediment contamination using the LOE. High SQGQ1 values at these stations were largely due to high chlordane concentrations.

The SQGQ1 value at SWZ04, was just under 1.0, the threshold for a high sediment contamination, and we classified this station as moderately contaminated based on the LOE. The remaining Switzer Creek sediments sampled in August and October were also classified as being moderately contaminated based on the LOE. None of the August or October sediments had SQGQ1 values greater than 1.0 (but all had SQGQ1 values > 0.50), and there were fewer than 5 chemicals exceeding their respective SQG values in these samples. The only other station with a SQGQ1 value greater than 1.0 was B Street/Downtown Piers station BST01 sampled in February 2004 (SQGQ1 = 1.883). This was due to a high concentration of copper (2,960 mg/kg dry wt.). Although copper in the BST01 sediment was high in February, the concentration of copper in tissues of clams exposed to this sediment was not elevated beyond those exposed to reference station sediments (see below). Because there were few individual chemicals exceeding their respective SQG values in the remaining samples and none with SQGQ1 values greater than 1.0, all other B Street/Downtown Piers and Downtown Anchorage stations were classified as being moderately contaminated based on the LOE (Table 4-1).

Table 4-1. Calculated summations, quotients and prediction limits for definitive sediment metal and organic chemistry analyses.

Station	Total PCBs (ng/g)	PCBs > CBGV(400) & 95%UPL	Metals > ERMs & 95% UPL	Chlordanes (ng/g)	Chlor > 4.77 & 95%UPL	Total PAHs (µg/g oc)	PAHs >CBGV (1800) & 95%UPL	Total SQGs & 95% UPLs exceeded	SQG Quotient	SQGQ > 95% UPL	LOE Summary
Feb 04										0.306	
SWZ01	536.0	X		80.2	X	495.96		2	2.055	X	High
SWZ02	334.3		Zn	64.6	X	185.87		2	1.734	X	High
SWZ04	176.1		Zn	21.3	X	176.09		2	0.922	X	Moderate
Aug. 04										0.291	
SWZ01	42.1			7.9	X	40.43		1	0.507	X	Moderate
SWZ02	45.6			14.4	X	77.71		1	0.609	X	Moderate
SWZ04	48.9			10.8	X	69.37		1	0.579	X	Moderate
Oct. 04										0.404	
SWZ01	32.9			18.5	X	72.71		1	0.781	X	Moderate
SWZ02	32.9		Zn, Hg	3		80.51		2	0.623	X	Moderate
SWZ04	178.9		Cu	17.5	X	92.55		2	0.889	X	Moderate
Feb 04										0.306	
BST01	78.2		Cu, Zn	3		390.54		2	1.883	X	High
BST04	83.9			3		599.49		0	0.565	X	Moderate
BST07	79.3			3		1005.18		0	0.613	X	Moderate
Aug. 04										0.291	
BST01	38.9		Hg	3		99.34		1	0.403	X	Moderate
BST04	32.9		Hg	3		74.39		1	0.359	X	Moderate
BST07	32.9		Hg	3		730.64		1	0.392	X	Moderate

Table 4-1. Calculated summations, quotients and prediction limits for definitive sediment metal and organic chemistry analyses.

Station	Total PCBs (ng/g)	PCBs > CBGV(400) & 95%UPL	Metals > ERMs & 95% UPL	Chlordanes (ng/g)	Chlor > 4.77 & 95%UPL	Total PAHs (µg/g oc)	PAHs >CBGV (1800) & 95%UPL	Total SQGs & 95% UPLs exceeded	SQG Quotient	SQGQ > 95% UPL	LOE Summary
Oct. 04										0.404	
BST01	52.1			3		76.63		0	0.569	X	Moderate
BST04	38.1			3		231.34		0	0.531	X	Moderate
BST07	32.9			3		647.95		0	0.527	X	Moderate
Feb. 04										0.306	
DAC02	109.1			3		94.91		0	0.640	X	Moderate
DAC03	968.7	X		3		317.44		1	0.872	X	Moderate
DAC04	165.1			15.3	X	130.48		1	0.620	X	Moderate
Aug. 04										0.291	
DAC02	36.6		Hg	3		22.99		1	0.508	X	Moderate
DAC03	162.3		Hg, Ag	3		156.21		2	0.645	X	Moderate
DAC04	71.9		Hg	10.6	X	45.59		2	0.553	X	Moderate
Oct. 04										0.404	
DAC02	66.6			3		61.43		0	0.488	X	Moderate
DAC03	311.1			3		43.55		0	0.771	X	Moderate
DAC04	69.9			24.5	X	52.41		1	0.760	X	Moderate
Feb. 04										0.306	
2229	32.9			3		123.50		0	0.173		Low
2238	32.9			3		12.07		0	0.241		Low
2243	32.9			3		26.05		0	0.194		Low

Table 4-1. Calculated summations, quotients and prediction limits for definitive sediment metal and organic chemistry analyses.

Station	Total PCBs (ng/g)	PCBs > CBGV(400) & 95%UPL	Metals > ERMs & 95% UPL	Chlordanes (ng/g)	Chlor > 4.77 & 95%UPL	Total PAHs (µg/g oc)	PAHs >CBGV (1800) & 95%UPL	Total SQGs & 95% UPLs exceeded	SQG Quotient	SQGQ > 95% UPL	LOE Summary
2433	32.9			3		39.08		0	0.185		Low
2441	32.9			3		23.21		0	0.267		Low
Aug. 04										0.291	
2229	32.9			3		115.51		0	0.172		Low
2238	32.9			3		13.02		0	0.223		Low
2243	32.9			3		16.12		0	0.204		Low
2433	32.9			3		347.45		0	0.205		Low
2441	32.9			3		6.55		0	0.263		Low
Oct. 04										0.404	
2229	43.8			3		42.92		0	0.203		Low
2238	32.9			3		3.16		0	0.244		Low
2243	32.9			3		5.89		0	0.221		Low
2433	32.9			3		15.61		0	0.190		Low
2441	32.9			3		23.17		0	0.361		Low

4.2.2 Sediment Toxicity

Unionized ammonia and grain size are two important sediment characteristics that may affect toxicity test organisms and therefore confound toxicity test results. Unionized ammonia concentrations in the interstitial waters of all samples were well below the no-observed effect concentration for the amphipod *Eohaustorius estuarius* at the beginning and end of all tests (NOEC = 0.8 mg/L; USEPA 1994). This indicates that interstitial water unionized ammonia was not a confounding factor in the toxicity test results. Unionized ammonia in the overlying waters of all amphipod tests were also well below this threshold at the beginning of all tests. The Day 10 unionized ammonia concentration in SWZ04 sediment overlying water in the February 2004 test was 0.808 mg/L. Although this concentration was within the range where toxic effects might occur, the initial (Day 0) concentration in this sample was well below that expected to affect *E. estuarius*. In addition, the interstitial water concentration in this sample on Day 10 was 0.093 mg/L, approximately 10% of the overlying water concentration. Because this species is primarily associated with interstitial water, unionized ammonia probably did not play a role in the amphipod mortality observed in this sample. All sediment samples were below 70% clay (Appendix B), indicating that grain size was not a confounding factor (Tay *et al*. 1998).
The magnitude of sediment toxicity was greatest in the February samples. Amphipod mortality was observed in some reference station samples, particularly in February. Samples from reference stations 2238, 2243, and 2441 were significantly toxic to amphipods during this sampling period. Relatively low amphipod survival was also observed in samples from station 2243 in August and October. Amphipod survival exceeded the 95% LPL in all reference station samples during all sample periods. In addition, none of the reference station pore water samples had significantly reduced sea urchin fertilization in any of the sampling periods. Based on the LOE, therefore, all of the reference stations were categorized as having a low degree of sediment toxicity.

Sediments from Switzer Creek were highly toxic to both test species in February 2004. Amphipod survival was 0%, 2%, and 5% in samples from SWZ01, SWZ02, and SWZ04, respectively. Samples from SWZ01, and SWZ02 were almost completely toxic to sea urchin sperm during this period. Based on the LOE, all Switzer Creek stations were categorized as having high sediment toxicity in February. Switzer Creek sediments continued to be toxic to amphipods in August, but of the three stations, only SWZ04 (30% survival) exceeded the 95% LPL. None of the stations were toxic to sea urchin fertilization during this time. Station SWZ04 was categorized as having high sediment toxicity in August 2004, and stations SWZ01 and SWZ02 were categorized as having low toxicity based on the LOE. No significant toxicity was observed using either protocol in any Switzer Creek samples collected in October. All three stations were categorized as having low toxicity during October.

Amphipod survival was significantly lower than the controls in all B Street/Downtown Pier stations in February. Survival was 64%, 62%, and 68% in BST 01, BST04, and BST07, respectively. Amphipod survival at all stations was greater than the 95% LPL, and none of the pore water samples from the B Street stations were toxic to sea urchin fertilization. No significant toxicity to amphipods or sea urchin fertilization was observed in any of the B

Street/Downtown Pier stations in August or October. All of these stations were categorized as having low toxicity during all sample periods.

All three Downtown Anchorage samples were significantly toxic to amphipods in February. Amphipod survival in DAC04 (39% survival) was the only one that was less than the 95% LPL. Pore water from DAC04 was also significantly toxic to sea urchin fertilization in February 2004, and fertilization was less than the 95% LPL in this sample. Based on the LOE criteria, DAC04 was classified as having high toxicity during this sampling period. Pore water from DAC02 and DAC03 were also significantly toxic to sea urchin fertilization, and fertilization was less than the 95% LPL in these samples. These stations were classified as having moderate toxicity in February, based on the LOE criteria. Toxicity to amphipods was also observed in the DAC04 sample in August, but survival was greater than the 95% LPL during this period. Significant toxicity to sea urchin fertilization was observed in DAC02 pore water, and fertilization was less than the 95% LPL. Based on the LOE criteria, DAC02 was classified as having moderate toxicity in August, and DAC03 and DAC04 were classified as having low toxicity. None of the October samples were toxic to either test organisms, and all stations were classified as having low sediment toxicity based on the LOE criteria.

Amphipod mortality in the laboratory toxicity tests was highly correlated with chlordanes and total PCBs in these samples (Table 4-4), and with TOC (which was also correlated with a number of chemicals). Amphipod survival was also weakly correlated with mixtures of chemicals, quatified as the SQGQ1 value. Amphipod survival was not correlated with sediment grain size. Although correlations do not deomonstrate causality, these results suggest that amphipods in the laboratory exposures were responding to chemicals, and not physical factors. Stations with the highest toxicity to amphipods were also those with the most degraded benthic communities, and amphipod survival was negatively correlated with the BRI. Possible cause(s) of toxicity to amphipods were investigated using TIEs, and the results of these investigations are discussed below.

4.2.3 Toxicity Identification Evaluations (TIEs)

Toxicity Identification Evaluations were conducted on sediments from two stations, SWZ01 and DAC04. Samples from these stations had low amphipod survival in the February 2004 sampling period. Approximately 40 L of sediment was collected from each station in April 2004 and a series of solid-phase and porewater toxicity tests were conducted with each sample to determine the magnitude of toxicity in both matrices. Amphipod survival in solid-phase samples collected in was 23% and 0%, in DAC04 and SWZ01, respectively. Because minimal toxicity was observed in porewater extracted from these samples, solid-phase procedures were used in subsequent TIEs, except where noted. Prior to initiation of the TIEs, these samples were analyzed to determine whether confounding factors such as unionized ammonia or hydrogen sulfide exceeded published toxicity thresholds for *E. estuarius*. The highest unionized ammonia concentration measured in these samples was 0.114 mg/L, well below the un-NH3 threshold effect concentration (0.8 mg/L). The highest hydrogen sulfide concentration was 0.09 mg/L, well below the H2S LC50 (0.198 mg/L)

The two primary solid-phase TIE procedures used in these experiments were addition of Ambersorb 563 to reduce bioavailability of organic chemicals, and addition of SIR-300 to reduce bioavailability of cationic metals. Amersorb 563 is a spherical carbonaceous resin (~300 µm diameter) that has been shown to be effective at reducing toxicity of non-polar organic chemicals in a variety of applications (Kosian et al. 1999). SIR-300 is a spherical amino-acetate resin (~350 µm) that has been shown to be effective at reducing toxicity due to divalent metals such as copper (Burgess et al. 2000). In addition to these treatments, the DAC04 solid-phase TIE included the addition of coconut charcoal, a fined-grain carbon that reduces bioavailability of organic chemicals in sediment (Ho et al. 2004).

A series of preliminary experiments were conducted with both sediment samples to verify the magnitude of toxicity and investigate appropriate volumes of Ambersorb, and SIR-300. These showed that both samples were toxic when diluted to 25% with control sediment. These also showed that additions of 20% SIR-300 and 15% Ambersorb were appropriate for TIEs with DAC04 and SWZ01 sediments when these were diluted to 25% (data not shown). A 15% addition of coconut charcoal was used in the solid-phase TIE with DAC04. Toxicity of all solid-phase TIE treatments was assessed with standard 10-d amphipod tests. Sample volumes were 200 g of sediment with 5 amphipods in each replicate

In addition to solid-phase TIEs, a sediment elutriate TIE was conducted with sample from SWZ01. In this TIE, an elutriate of SWZ01 was prepared by mixing 50% v:v ratio of 20‰ seawater with SWZ01 sediment for 1 minute then letting this solution settle overnight. This water (labeled 100% elutriate in the TIE results) was then decanted off and subjected to standard Phase I TIE treatments. These included C8 solid-phase extraction to remove organic chemicals, elution of the C8 column with methanol, EDTA addition to bind cationic metals, cation column solid-phase extraction to remove metals, and elution of the cation column with hydrochloric acid. An additional treatment designed to assess toxicity due to mixtures of organic chemicals and metals consisted of adding EDTA to post C8 column rinsate. Appropriate blanks (controls) for all of these treatments consisted of subjecting 20‰ seawater to the same treatments. Toxicity of all elutriate TIE treatments was assessed with 10-d amphipod exposures using one animal in each replicate container (10 replicates per treatment). Amphipods were exposed to 10 ml test solution in scintillation vials, and test solutions were renewed on day 5.

Results TIEs of SWZ01 using Eohaustorius estuarius.

SWZ01 sediment diluted to 25% produced amphipod survival of 12% (Figure 4-1). Amphipod survival was 100% with the addition of Ambersorb, indicating toxicity was caused by an organic chemical. Amphipod survival was 80% with the addition of SIR-300, suggesting toxicity of SWZ01 could also be partly due to cationic metals (Fig. 4-1). Amphipod survival was greater than or equal to 88% in control sediment treated with the addition of Ambersorb and SIR-300, indicating no toxicity due to addition of the resins (data not shown). Amphipod survival was 20% in the treatment designed to assess dilution effects from the addition of the TIE resins, indicating the reduction in toxicity with the addition of Ambersorb and SIR-300 was not due to sediment dilution (see SWZ01 + 20% home sediment; Fig 4-1).

Amphipod survival was 60% in sediment elutriate prepared from SWZ01 sediment. Survival was 100% when the elutriate was filtered through a C8 solid-phase extraction (SPE) column. The column was then eluted with methanol, and 0% amphipod survival was observed in seawater spiked with the C8 column methanol eluate (Table 4-2). When results of these two TIE treatments are considered together, reduction of toxicity with C8 SPE and complete mortality in the column eluate, the results strongly suggest toxicity of SWZ01 sediment was due to non-polar organic chemicals. Toxicity of the elutriate sample was not reduced by any of the treatments designed to reduce toxicity due to cationic metals (EDTA addition, cation column solid phase extraction, cation column elution with hydrochloric acid; Table 4-2).

Results of the solid-phase and sediment elutriate TIEs indicate toxicity of SWZ01 sediment was caused by organic chemical(s). Toxicity was eliminated with treatments designed to remove organic chemicals. Our observation of high toxicity in the C8 column eluate supports this conclusion. Although toxicity of the solid-phase sample was greatly reduced with the addition of the metal binding resin SIR-300, this may have been due to binding of organic chemicals rather than metals. No treatments designed to reduce toxicity due to metals were effective in the sediment elutriate TIEs, and no toxicity was observed in the cation column HCl eluate.

The conclusion that organic chemicals are the likely cause of SWZ01 toxicity to amphipods is supported by the chemical analyses of this sample. Of the organic chemicals measured, total chordanes in the SWZ01 sample was 80 ng/g, approximately 13 times the ERM SQG value (6 ng/g), and 19 times the PEL SQG (4.77 ng/g; Table 4-1). In addition, amphipod mortality was more highly correlated with total chlordane concentrations than any other chemical constituent (Table 4-4). No metals exceeded their respective ERMs in the SWZ01 sediment collected in February 2004, and amphipod mortality was not correlated with metals in this study (Table 4-4). While elevated concentrations of other organic chemicals were also measured in SWZ01 sediment, none of these exceeded their respective guideline values. Taken as a weight-of-evidence, these results suggest toxicity of SWZ01 sediment was likely due to mixtures of organic chemicals containing high concentrations of chlordane. Confirmation of chlordane as a primary cause of toxicity would require additional Phase II TIE steps such as HPLC fractionation of the C8 column (or Ambersorb) eluate, and toxicity tests and chemical analyses of the HPLC fractions. These steps were beyond the scope of the current study.

Results of TIEs of DAC04 using Eohaustorius estuarius.

DAC04 sediment diluted to 25% produced amphipod survival of 44% (Figure 4-2). Amphipod survival was 84% with the addition of Ambersorb, indicating toxicity was caused by an organic chemical. Amphipod survival was 88% with the addition of fine-grain coconut charcoal, also suggesting toxicity due to an organic chemical. Survival was 60% with the addition of SIR-300, suggesting minimal toxicity of DAC04 due to cationic metals (Fig. 4-2). Amphipod survival was greater than or equal to 88% in control sediment treated with the addition of Ambersorb, coconut charcoal and SIR-300 (data not shown). Amphipod survival was 40% in the treatment designed to assess dilution effects from the addition of the TIE resins, indicating the reduction in toxicity with the addition of Ambersorb and coconut charcoal was not due to sediment dilution (see DAC04 + 20% home sediment; Fig 4-2).

Total chlordane in the February 2004 DAC04 sample was 15.3 ng/g, 3 times the PEL SQG value (4.77 ng/g). No other organic chemical SQGs were exceeded in this sample, and no metal ERMs were exceeded. The SQGQ1 calculated for this sample was 0.616, which suggests chemical mixtures enriched beyond those of the reference stations. Taken as a whole, these results suggest toxicity of DAC04 sediments was likely due to organic chemicals, but Phase II TIE procedures would be required to verify which compounds are responsible. Based on the weight-of-evidence, chlordane is a likely candidate for follow-up TIE work.

Figure 4-1. Results of Phase I TIE with SWZ01 sediment (see text for details).

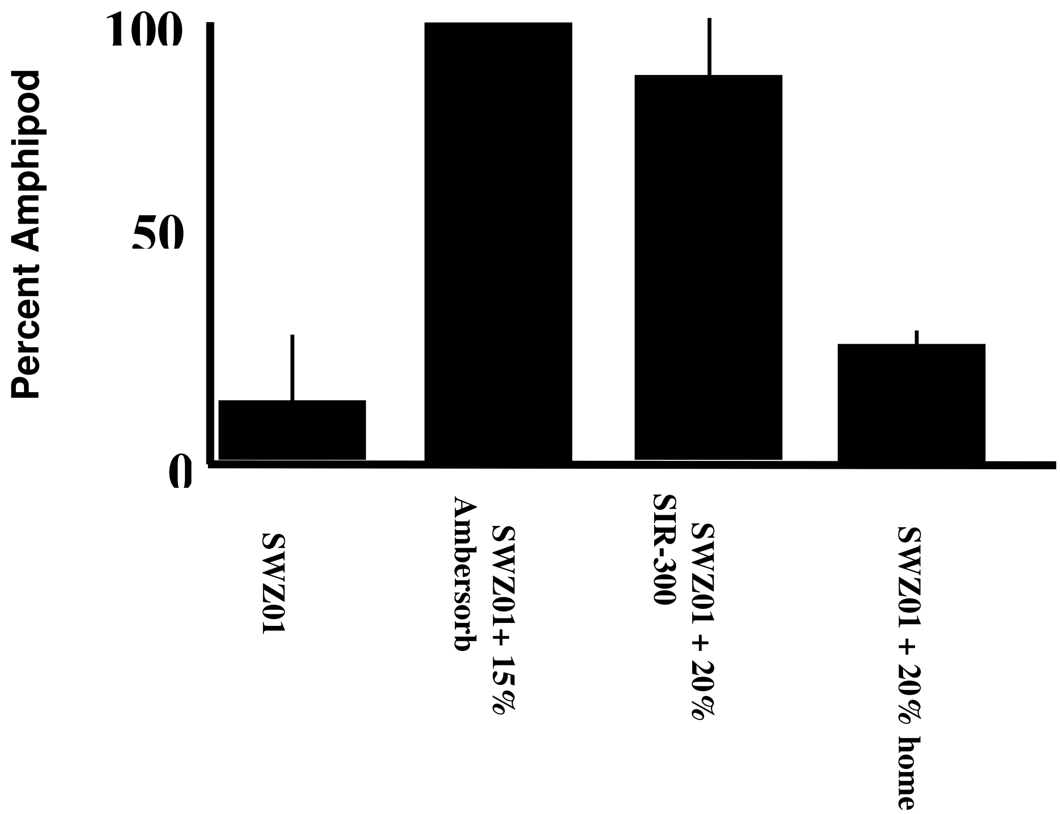
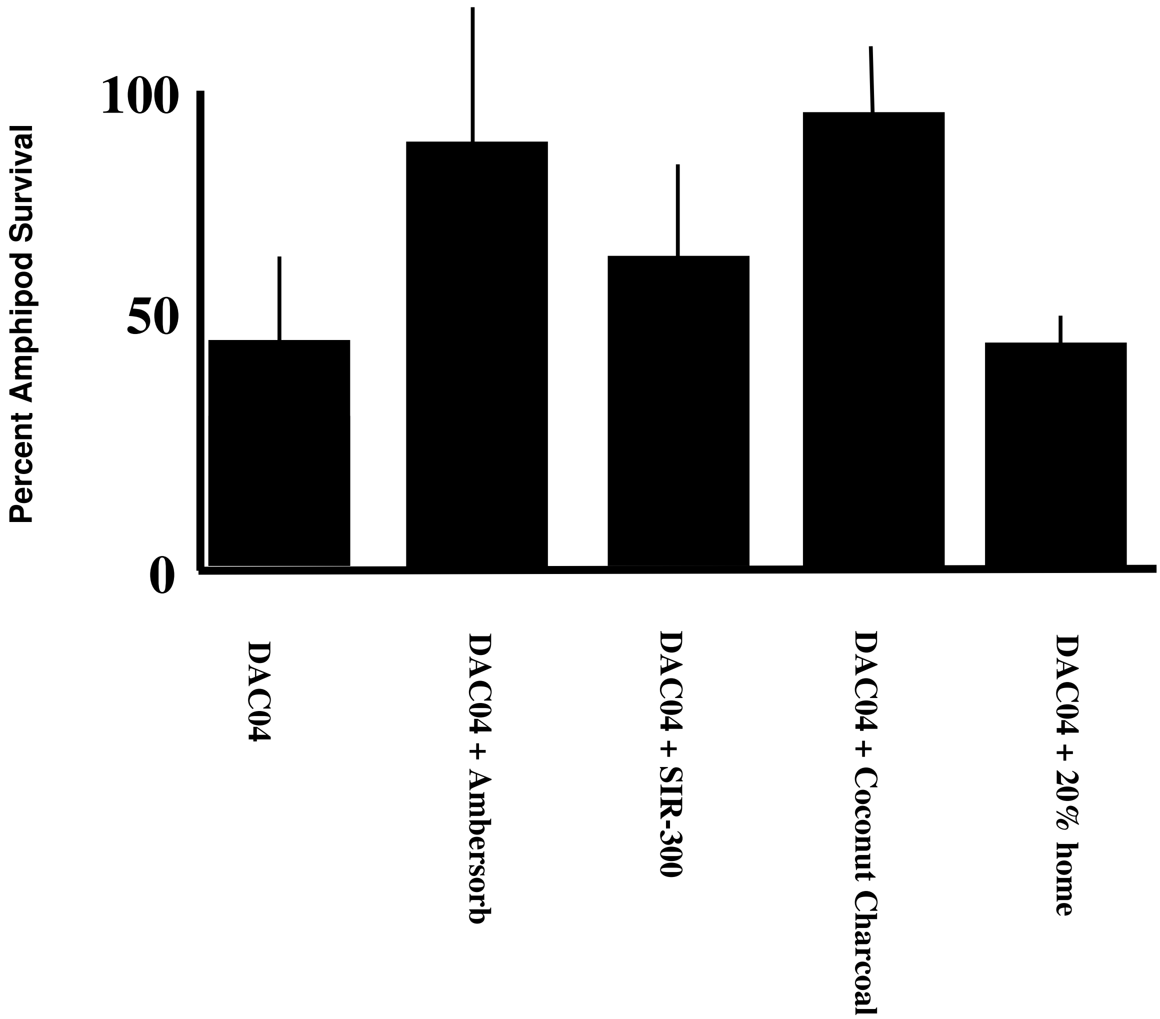


Table 4-2. Results of TIE using sediment elutriate from SWZ01.

TIE Treatments	Proportion Amphipod Survival	
	Control/Treatment Blank	100% Sediment Elutriate
Baseline	1.00	0.60
EDTA	0.90	0.50
C8 Column	0.90	1.00
C8 Eluate	0.90	0.00
C8 Col.+EDTA	1.00	0.90
Cation Column	0.80	0.40
Cation Eluate	0.90	0.90

Figure 4-2. Results of Phase I TIE with DAC04 sediment.



4.2.4 Benthic Community Composition

The BRI values for all reference stations except station 2441 were RL 1 (slight deviation from reference). Relative to the stations of concern, the numbers of species and Shannon-Weiner diversity indices were higher for all reference stations. In addition, total abundances of organisms were higher at the reference stations. The BRI value was somewhat higher for reference station 2441, and this station was classified as RL 2 (biodiversity loss), though this BRI value did not exceed the 95% reference station UPL. Station 2441 had relatively high numbers of the cnidarians *Edwardsia californica* (Anthozoa – Actinaria), which has a relatively higher pollution tolerance score. In addition, this station had few crustacea, and higher numbers of polychaetes with high pollution tolerance scores (e.g., *Leitoscoloplos pugettensis, Dorvillea longicornis*). All reference stations were categorized as Low impact, using the LOE criteria for benthic community characteristics (Table 4-5).

The three Switzer Creek stations had the highest BRI values of all the stations characterized in this study, and all were classified as RL 3 (community function loss). There were low numbers of species at all three Switzer Creek stations, and few crustacea. Although some molluscs were present, these tended to be species with higher pollution tolerance scores (e.g., *Theora lubrica*). The metrics for number of species, and Shannon–Weiner diversity were lower than the 95% LPL based on reference conditions (except S-W at SWZ02). In addition, abundances at the Switzer Creek stations were lower than at the other stations. The species assemblages at the Switzer Creek stations were dominated by pollution tolerant polychaete species, particularly *Capitella capitata* and *Dorvillea longicornis*. Based on the LOE criteria for benthic communities, all three Switzer Creek stations were categorized as High Impact (Table 4-5).

Two of the three B Street/Downtown Pier stations had degraded benthic communities relative to the reference stations. BST01 and BST04 had BRI values that exceeded the 95% UPL, and both stations were classified as RL 2 (biodiversity loss). Both of these stations had fewer species than the 95% LPL, and the Shannon-Weiner index for station BST01 was lower than the 95% LPL for this metric. Although BST01 and BST04 were classified as High impact based on the LOE criteria, these stations had mixed benthic community characteristics. For example, some sensitive taxa were found at both stations (e.g., amphipods *Heterophoxus* sp., polychaetes *Mediomastus sp*., and *Dipplocirrus sp*.), but higher numbers of pollution tolerant taxa were also found (*Theora lubrica, Musculista stenhousei, Capitella capitata*). Station BST07 was classified as Low impact based on the LOE criteria (no individual criteria were exceeded). This station had somewhat higher abundances of macroinvertebrates than the other two stations at this site, and also had more species and a higher S-W diversity score. Although this station was also classified as RL 2, the BRI value was lower than the 95% UPL based on the reference stations (Table 4-5).

At the Downtown Anchorage, DAC02 and DAC04 were classified as High Impact stations based on the LOE criteria. Both had BRI values that exceeded the 95% UPL based on the reference stations, and both had fewer species than the reference stations. DAC02 was classified as RL 3 (community function loss), and DAC04 was classified as RL 2 (biodiversity loss). Both stations had mixtures of pollution sensitive and pollution tolerant species. Both had relatively high numbers of sensitive polychaete species (e.g., *Pseudopolydora paucibranchiata, Prionospio* *heterobrachia, Mediomastus sp.*), and these were mixed with relatively high numbers of tolerant species (e.g., *Leitoscoloplos pugettensis, Theora lubrica*). Both stations had few crustacea. Although station DAC03 was similar to the other two Downtown Anchorage stations in terms of species composition, this station was classified as Moderate Impact, because the BRI value did not exceed the 95% UPL. The number of species and Shannon-Weiner indices were both lower than their respective 95% LPLs. This station also had the lowest abundance of macroinvertebrates of the three Downtown Anchorage stations.

Spearman Rank correlations showed that benthic community characteristics in these samples were correlated with a number of physical, chemical, and biological variables (Table 4-6). The BRI values were highly positively correlated with TOC in these samples (note that TOC was correlated with many of the chemicals and with chemical mixtures). BRI values were also highly correlated with total metals, the SQGQ1 values, total PCBs and chlordane. The BRI was also negatively correlated with amphipod survival in the laboratory toxicity tests. The BRI was not correlated with sediment grain size. Although statistical correlations do not demonstrate causal relationships, these results suggest that the benthic communities at these stations were responding to chemical factors and not physical factors. Stations with the most impacted benthic communities were the most contaminated stations, and were also those with the highest amphipod mortality in laboratory toxicity tests.

Table 4-3. Summary of toxicity test results.

Station	*Eohaustorius* survival in whole sediment				Sea urchin fertilization in 100% porewater				LOE
	Proportion Survival	significant t-test (a)	< 75% cont	< lower 95% PL	Proportion Fertilized	significant t-test (a,d)	< 88% cont.	< lower 95% PL (100%PW)	Impact Summary
Feb 04.			0.72	0.45			0.80	0.80	
SWZ01	0.00	X	X	X	0.03	X	X	X	High
SWZ02	0.02	X	X	X	0.05	X	X	X	High
SWZ04	0.05	X	X	X	0.78		X	X	High
Aug. 04			0.70	0.50			0.86	0.90	
SWZ01	0.51	X	X		0.94				Low
SWZ02	0.51	X	X		0.92				Low
SWZ04	0.30	X	X	X	0.95				High
Oct. 04			0.70	0.55			0.87	0.92	
SWZ01	0.76	X			0.95				Low
SWZ02	0.80	X			0.97				Low
SWZ04	0.84	X			0.97				Low
Feb 04			0.72	0.45			0.80	0.80	
BST01	0.64	X	X		0.83				Low
BST04	0.62	X	X		0.82				Low
BST07	0.68	X	X		0.85				Low
Aug. 04			0.70	0.50			0.86	0.90	
BST01	0.80				0.82				Low
BST04	0.86				0.94				Low
BST07	0.85	X			0.94				Low
Oct. 04			0.70	0.55			0.87	0.92	
BST01	0.79	X			0.98				Low
BST04	0.80				0.95				Low

Table 4-3. Summary of toxicity test results.

	Eohaustorius survival in whole sediment				Sea urchin fertilization in 100% porewater				
Station	Proportion Survival	significant t-test (a)	< 75% cont	< lower 95% PL	Proportion Fertilized	significant t-test (a,d)	< 88% cont.	< lower 95% PL (100%PW)	LOE Impact Summary
BST07	0.79				0.95				Low
Feb. 04			0.72	0.45			0.80	0.80	
DAC02	0.56	X	X		0.52	X	X	X	Moderate
DAC03	0.70	X	X		0.79	X	X	X	Moderate
DAC04	0.39	X	X	X	0.58	X	X	X	High
Aug. 04			0.70	0.50			0.86	0.90	
DAC02	0.86				0.13	X	X	X	Moderate
DAC03	0.88				0.90				Low
DAC04	0.63	X	X		0.93				Low
Oct. 04			0.70	0.55			0.87	0.92	
DAC02	0.82	X			0.92				Low
DAC03	0.88				0.91				Low
DAC04	0.87				0.97				Low
Feb 04			0.72	0.45			0.80		
2229	0.87	X			0.87				Low
2238	0.58	X	X		0.86				Low
2243	0.68	X	X		0.89				Low
2433	0.83	X			0.83				Low
2441	0.68	X	X		0.84				Low
Aug. 04			0.70	0.50			0.86		
2229	0.81	X			0.95				Low
2238	0.83	X			0.92				Low
2243	0.61		X		0.94				Low

Table 4-3. Summary of toxicity test results.

	Eohaustorius survival in whole sediment				Sea urchin fertilization in 100% porewater				
Station	Proportion Survival	significant t-test (a)	< 75% cont	< lower 95% PL	Proportion Fertilized	significant t-test (a,d)	< 88% cont.	< lower 95% PL (100%PW)	LOE Impact Summary
2433	0.96				0.92				Low
2441	0.94				0.93				Low
Oct. 04			0.70	0.55			0.87		
2229	0.84	X			0.99				Low
2238	0.88				0.98				Low
2243	0.63	X	X		0.97				Low
2433	0.95				0.97				Low
2441	0.93				0.99				Low

(a) Calculated using paired-sample t-test, one-tailed, α =0.05. P-values reported in Appendix D. Grey shaded cells indicate difference from controls with t-tests, difference from MSD thresholds, or difference from 95% prediction limits, as appropriate.

Table 4-4. Spearman Rank Correlation matrix showing factors correlated with amphipod survival in laboratory exposures (n = 42).

	Spearman rho value
BRI	-0.493* (n = 14)
TOC	-0.399**
Grain Size	0.190
Total metals quotient	-0.241
SQGQ1	-0.331*
Chlordanes	-0.492***
PAHs	-0.233
PCBs	-0.383**

* significant @ p = 0.05, ** significant @ p = 0.01; *** significant @ p = 0.001

Table 4-5. Summary of benthic community measures.

Station	Calc. BRI (95% UPL = 46.62)	Station Response Level	Abundance(95% LPL = NC)	No. Species (95% LPL = 18.58)	S-W (95% LPL = 2.27)	% fines	TOC (mg/dry kg)	LOE Impact Summary
SWZ01	64.24	RL 3	35.00	10.33	1.84	54.6	4.33	High
SWZ02	63.16	RL 3	55.00	15.00	2.29	53.9	3.62	High
SWZ04	55.57	RL 3	31.00	9.00	1.57	58.7	3.50	High
BST01	51.78	RL 2	54.33	14.00	2.06	58.6	1.96	High
BST04	48.18	RL 2	78.33	17.67	2.33	87.4	1.96	High
BST07	43.38	RL 2	89.33	25.33	2.77	73.5	2.23	Low
DAC02	53.89	RL 3	66.67	15.00	2.34	75.8	2.49	High
DAC03	45.91	RL 2	36.67	9.67	1.90	62.7	2.02	Moderate
DAC04	49.65	RL 2	94.67	18.00	2.24	67.5	2.77	High
2229	32.78	RL 1	74.67	23.00	2.70	22.8	0.75	Low
2238	33.58	RL 1	144.00	25.67	2.53	61.3	1.06	Low
2243	36.59	RL 1	93.67	20.67	2.60	31.3	0.51	Low
2433	33.07	RL 1	86.67	26.67	2.78	36.2	0.62	Low
2441	43.64	RL 2	198.67	24.33	2.41	81.8	2.33	Low

(b) Based on calculated BRI; RL = Response Level: R = reference; RL 1 = slight deviation; RL 2= biodiversity loss; RL 3 = Community function loss. Grey shaded cells indicate difference from 95% prediction limits. NC = lower prediction limit not calculated due to reference station variability.

Table 4-6. Spearman Rank Correlation matrix showing factors correlated with BRI (n = 14).

	Spearman rho value
Amphipod survival	-0.493*
TOC	0.851***
Grain Size	0.231
Total metals quotient	0.798***
SQGQ1	0.781***
Chlordane	0.652**

Table 4-6. Spearman Rank Correlation matrix showing factors correlated with BRI (n = 14).

PAHs	-0.187
PCBs	0.678**

* significant @ p = 0.05; ** = significant @ P = 0.01; *** = significant @ p = 0.001

4.2.5 Reference Station Characteristics

The ranges of depths at the reference stations were comparable to those of the study stations. While the ranges of grain sizes at the reference stations were similar to those at the study stations, the mean percent fine-grained sediments at the references stations were generally lower than those at many of the study stations. In particular, sediments at reference stations 2229 and 2433 were comprised of considerably lower percentages of fined-grained particles than those at the majority of study stations. Similarly, total organic carbon concentrations were generally lower in reference station sediments relative to those in the study stations sediments. This was particularly true when compared to sediments from Switzer Creek, where TOC was as high as 5.57%. Except for reference station 2441 (mean TOC = 2.32%), mean TOCs at the other reference stations were less than 1.0%.

Table 4-7. Means and ranges of physical characteristics of reference and study stations during February, August, and October 2004 sampling periods.

Station	Depth (m) Range and (mean)	Fines (%) Range and (mean)	TOC (%) Range and (mean)
2229	12.6 – 14.5 (13.3)	15.4 – 22.8 (18.9)	0.32 – 0.75 (0.48)
2238	3.7 – 4.0 (3.9)	54.3 – 62.7 (59.4)	0.88 – 1.06 (0.97)
2243	4.0 – 4.7 (4.3)	27.1 –32.3 (30.2)	0.40 – 0.54 (0.48)
2433	9.2 – 9.5 (9.3)	31.8 –36.2 (33.3)	0.62 – 0.65 (0.64)
2441	13.5 – 14.9 (14.3)	55.4 –81.8 (70.8)	2.29 – 2.35 (2.32)
SWZ01	10.3 – 10.7 (10.5)	38.4 –59.6 (50.9)	4.10 – 4.85 (4.43)
SWZ02	10.4 – 11.1 (10.8)	53.9 – 68.1 (61.0)	2.93 – 5.57 (4.04)
SWZ04	3.6 – 10.0 (7.5)	36.4 – 58.7 (48.0)	2.72 – 3.87 (3.36)
BST01	5.3 – 10.1 (7.6)	58.6 – 73.4 (57.5)	1.96 – 2.25 (2.14)
BST04	7.9 – 11.0 (9.6)	68.2 – 87.4 (78.4)	1.96 – 2.29 (2.09)

Table 4-2. Means and ranges of physical characteristics of reference and study stations during February, August, and October 2004 sampling periods.

BST07	7.2 – 9.7 (8.3)	61.7 –74.9 (70.0)	2.23 – 2.53 (2.35)
DAC02	5.3 – 5.7 (5.5)	75.6 – 82.7 (78.0)	2.49 –2.86 (2.61)
DAC03	5.2 – 5.3 (5.3)	62.7 – 75.1 (69.3)	1.88 – 2.46 (2.12)
DAC04	4.6 – 6.0 (5.4)	49.2 – 67.5 (57.6)	1.39 – 2.77 (2.01)
All reference stations	3.7 – 14.9	15.4 – 81.8	0.32 – 2.35
All study stations	3.6 – 11.1	36.4 - 87.4	1.39 – 5.57

5.0 WEIGHT OF EVIDENCE FOR AQUATIC LIFE IMPAIRMENT

The weight of evidence (WOE) approach described in previous San Diego Bay sediment studies (SCCWRP 2004; Brown and Bay 2005) was applied to these data using the WOE key presented in Table 3-1. The three possible WOE classifications (Impairment Likely, Possible, or Unlikely) for the Phase II study are presented in Table 5-1. These are based on possible combinations of the three LOE classifications (High, Moderate, Low) for each of the three indicators of possible Aquatic Life Impairment assessed synoptically in August 2004, and for two of the three indicators assessed in February and October 2004. For additional temporal comparison, Table 5-2 presents WOE classifications for the same stations analyzed as part of the Phase I study conducted in July 2003. The Phase I study included all three indicators (chemistry, toxicity, benthics).

In situations where the chemistry and toxicity LOE resulted in high classifications, site-specific impairments of aquatic life due to exposure of chemicals of possible concern were considered likely. These included February samples from Switzer Creek stations SWZ01 and SWZ02, and the August 2004 sample from SWZ04. The only other station classified as likely impaired was Downtown Anchorage station DAC02 sampled in August 2004. The majority of stations in this study were classified as possibly impaired based on the WOE (Table 5-1). This is partly a result of uncertainty due to the lack of benthic community data in the February and October sampling periods, but 6 of 9 stations of concern were classified as possibly impaired in August 2004, even with the additional benthic community data. This was due to moderate classifications among the 3 sediment quality indicators, and also due inconsistent LOE classifications among the 3 indicators. In most cases, classifications of stations as “possibly impaired” based on the WOE were a result of low sediment toxicity in the August and October sampling periods. All 5 of the reference stations were classified as unlikely impaired during all three sampling periods.

The Phase I data from samples collected in July 2003 provide additional information on temporal variability at these stations. These data were compared to those from the August 2004 sampling period because both represent similar index periods for San Diego Bay benthic communities. While all of the reference stations were classified as unlikely impaired in Phase I and II, there was agreement in overall WOE classifications in only 4 of the 9 stations of concern between the Phase I and II studies. For example, all three of the Switzer Creek stations were classified as likely impaired in the Phase I study, while 2 of these three stations were classified as possibly impaired in August 2004 (Tables 5-1 and 5-2). The differences in classification are apparently due to greater toxicity in the Phase I study (this study included the SWI toxicity test), and more consistent agreement among the three indicators.

Table 5-1. Aquatic Life Impairment Table.

Station	Chemistry	Toxicity	Benthic Community	Site-Specific Impairment From CoPCs
Feb 04.				
SWZ01	High	High	NM	Likely
SWZ02	High	High	NM	Likely
SWZ04	Moderate	High	NM	Possible
Aug. 04				
SWZ01	Moderate	Low	High	Possible
SWZ02	Moderate	Low	High	Possible
SWZ04	Moderate	High	High	Likely
Oct. 04				
SWZ01	Moderate	Low	NM	Possible
SWZ02	Moderate	Low	NM	Possible
SWZ04	Moderate	Low	NM	Possible
Feb 04				
BST01	High	Low	NM	Possible
BST04	Moderate	Low	NM	Possible
BST07	Moderate	Low	NM	Possible
Aug. 04				
BST01	Moderate	Low	High	Possible
BST04	Moderate	Low	High	Possible
BST07	Moderate	Low	Low	Unlikely
Oct. 04				
BST01	Moderate	Low	NM	Possible
BST04	Moderate	Low	NM	Possible
BST07	Moderate	Low	NM	Possible

Table 5-1. Aquatic Life Impairment Table.

Station	Chemistry	Toxicity	Benthic Community	Site-Specific Impairment From CoPCs
Feb. 04				
DAC02	Moderate	Moderate	High	Likely
DAC03	Moderate	Moderate	Moderate	Likely
DAC04	Moderate	High	High	Likely
Aug. 04				
DAC02	Moderate	Moderate	NM	Possible
DAC03	Moderate	Low	NM	Possible
DAC04	Moderate	Low	NM	Possible
Oct. 04				
DAC02	Moderate	Low	NM	Possible
DAC03	Moderate	Low	NM	Possible
DAC04	Moderate	Low	NM	Possible
Feb 04				
2229	Low	Low	NM	Unlikely
2238	Low	Low	NM	Unlikely
2243	Low	Low	NM	Unlikely
2433	Low	Low	NM	Unlikely
2441	Low	Low	NM	Unlikely
Aug. 04				
2229	Low	Low	Low	Unlikely
2238	Low	Low	Low	Unlikely
2243	Low	Low	Low	Unlikely
2433	Low	Low	Low	Unlikely
2441	Low	Low	Low	Unlikely

Table 5-1. Aquatic Life Impairment Table.

Station	Chemistry	Toxicity	Benthic Community	Site-Specific Impairment From CoPCs
Oct. 04				
2229	Low	Low	NM	Unlikely
2238	Low	Low	NM	Unlikely
2243	Low	Low	NM	Unlikely
2433	Low	Low	NM	Unlikely
2441	Low	Low	NM	Unlikely

Table 5-2. Summary WOE for Aquatic Life Impairment from Phase I assessment in July 2003.

Aquatic Life Impairment Table				
Station	**Chemistry**	**Toxicity**	**Benthos**	**Site Specific Impairment from CoPCs**
SWZ01	Moderate	Moderate	Moderate	Likely
SWZ02	Moderate	Moderate	Moderate	Likely
SWZ04	Moderate	Moderate	Moderate	Likely
BST01	Moderate	Low	Low	Unlikely
BST04	Moderate	Low	Moderate	Possible
BST07	Moderate	Low	Low	Unlikely
DAC02	Moderate	Low	Moderate	Possible
DAC03	Moderate	Low	Moderate	Possible
DAC04	Moderate	Moderate	Moderate	Likely
2229	Low	Low	Low	Unlikely
2238	Low	Low	Low	Unlikely
2243	Low	Low	Low	Unlikely
2433	Low	Low	Low	Unlikely
2441	Low	Low	Low	Unlikely

5.1.1 Bioaccumulation

Except for selected metal, PAH, and PCB constituents, chemical concentrations in *Macoma* tissues after 28-d laboratory sediment exposures were generally low during all three sampling periods. At T_0 (unexposed clams) and T_{28} (after 28 days of sediment exposure), most clam tissues contained detectable levels of most metals (Appendix D). Clam tissues also contained a number of PAHs at T_{28} during all three sample periods. Except for low concentrations of DDE in clams exposed to the reference station sediment in February, no pesticides were detected in reference station clam tissues at any time in this study. Elevated PCBs were only detected in clams exposed to sediments from stations BAC04, DAC02 and DAC03. Only low concentrations of PCBs were detected in clam tissues from the other stations during this study.

Net bioaccumulation at each site (T_{28} – mean T_0) was calculated for each metal and for total PAHs, and those samples containing PCBs (Appendix D). Net bioaccumulation for these constituents was compared to the upper 95% prediction limit calculated from reference site values (Table 5-3). PAHs and PCBs were all less than the 95% UPL in all clams exposed to reference station sediments in February, August, and October. Metals were also low in clams exposed to reference station sediments. In February, aluminum exceeded the 95% UPL in clams from reference stations 2238 and 2433. In August, aluminum in clams from reference station 2433 exceeded the 95% UPL, nickel exceeded the 95% UPL in clams from stations 2433 and 2441, and selenium exceeded the 95% UPL in clams from reference station 2238. In October, tin exceeded the 95% UPL in clams from reference stations 2229 and 2243, and iron exceeded the 95% UPL in clams from reference station 2433. The greatest number of samples exceeding metal UPLs were observed in clams exposed to sediments collected in February and August; far fewer metal UPLs were exceeded in October. In February, tissues from clams exposed to SWZ01 sediments exceeded the 95% UPLs for aluminum, antimony, chromium, and molybdenum; SWZ04 had 95% UPL exceedances for aluminum, chromium, nickel, and tin. BST04 had 95% UPL exceedances for aluminum, barium, chromium, iron, nickel, tin, vanadium, zinc, and total PAHs; BST07 had exceedances for aluminum, chromium, molybdenum, and total PAHs. DAC02 had exceedances for aluminum, arsenic, barium, chromium, iron, tin, and total PCBs. DAC03 had exceedances for aluminum, chromium, nickel, tin, and total PCBs. In August, tissues from clams exposed to SWZ01 sediments exceeded the 95% UPLs for aluminum, antimony, arsenic, molybdenum, selenium, and tin; SWZ04 had 95% UPL exceedances for aluminum, antimony, arsenic, molybdenum, selenium, tin, and vanadium. BST04 had 95% UPL exceedances for aluminum, antimony, arsenic, chromium, iron, molybdenum, selenium, tin and total PAHs; BST07 had exceedances for selenium, total PCBs and total PAHs. DAC02 had exceedances for chromium, selenium, tin, total PCBs, and total PAHs. DAC03 had exceedances for aluminum, selenium, tin, and total PCBs.

Comparison to toxicity reference values (TRVs) were available for eight of the metals detected in clam tissues after 28 days of exposure. TRVs were available for PCBs (as Arochlor 1242 or 1254). Risks were calculated for the lesser scaup, based on clam ingestion and incidental sediment ingestion (Appendix F). No tissues exceeded metal TRV high values during any of the sample periods. A number of metals exceeded TRV low values in all three sampling periods. The majority of exceedances were TRV low values for selenium and copper in February, August and October 2004. Arochlor concentrations in tissues from clams exposed to stations DAC02 (as Arochlor 1254) and DAC03 (as Arochlor 1242) sediments were well above the TRV high values during all three sample periods. Arochlor (1242) concentrations in tissues from clams exposed to BST04 and BST07 exceeded the TRV high values in October. Selected PAHs were compared to TRV low values for naphthalene and benzo(a)pyrene. TRV low values for benzo(a)pyrene were exceeded in tissues from all stations in February, August, and October except reference stations 2238 and 2243.

Only subtle seasonal trends in bioaccumulation were evident in this study. The greatest number of exceedances of TRV low values occurred in clams exposed to sediment collected in February 2004 (21 metal TRV low values were exceeded). Thirteen and 16 metal TRV low values were exceeded in August and October, respectively. The magnitude of metal, PAH and PCB concentrations in clam tissues were not appreciably higher in any one sampling period.

5.1.2 Impairment to Aquatic Dependent Wildlife

A two-step process was used to determine whether impairment to aquatic dependent wildlife was possible or unlikely due to elevated tissue concentrations of chemicals of potential concern. Impairment was considered to be possible at stations where tissue concentrations exceeded both the 95% UPL for specific CoPCs and the TRV low values for these chemicals. In February these included SWZ04, BST04, BST07, DAC02, and DAC03 for benzo(a)pyrene, and BST04 for zinc. During this sampling period DAC02, and DAC03 were classified as possibly impaired due to PCBs. All other stations were considered unlikely impaired due to CoPCs during this sampling period.

In August, stations considered possibly impaired included SWZ01, SWZ04, BST04, BST07, DAC02, DAC03, and reference station 2238 for selenium. During this sampling period DAC02 and DAC03 were considered to be possibly impaired due to PCBs, and BST07, DAC02, and DAC03 were considered possibly impaired due to benzo(a)pyrene. All other stations were considered unlikely impaired due to tissue concentrations of CoPCs in August 2004.

In October 2004, stations considered possibly impaired included SWZ01, SWZ04, BST04, BST07, DAC02, and DAC03 for benzo(a)pyrene; SWZ04 for copper, BST04, DAC02, and DAC03 for PCBs. All other stations were considered unlikely impaired due to tissue concentrations of CoPCs in October 2004.

Table 5-3. Stations where bioaccumulation exceeded upper 95% prediction limit for reference site bioaccumulation.

February 2004

Analyte	95% UPL	SWZ01*	SWZ04	BST04*	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Aluminum	940.5	X	X	X	X	X	X		X		X	
Antimony	0.128	X										
Arsenic	3.565					X						
Barium	4.710			X		X						
Beryllium	0											
Cadmium	1.118											
Chromium	-0.036	X	X	X	X	X	X					
Cobalt	-.844											
Copper	16.898											
Iron	1367.159			X		X						
Manganese	14.631											
Mercury	0											
Molybdenum	0.304	X			X							
Nickel	-1.752		X	X			X					
Selenium	0.584											
Silver	0.563											

Table 5-3. Stations where bioaccumulation exceeded upper 95% prediction limit for reference site bioaccumulation.

February 2004

Analyte	95% UPL	SWZ01*	SWZ04	BST04*	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Strontium	25.473											
Thallium	0											
Tin	0.113		X	X		X	X					
Titanium	69.640											
Vanadium	2.850			X								
Zinc	97.589			X								
Total PCBs	0					X	X					
Total DDT	40.51											
Total PAHs	1996.48			X	X							

+ 95% upper prediction limit for reference site mean values, in mg/kg dw for metals, and ng/g dw for PAHs.

Table 5-3. (cont.). Stations where bioaccumulation exceeded upper 95% prediction limit for reference site bioaccumulation.

August 2004

Analyte	95% UPL	SWZ01*	SWZ04	BST04	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Aluminum	940.5	X	X	X			X				X	
Antimony	0.128	X	X	X								
Arsenic	3.565	X	X	X								
Barium	4.710											
Beryllium	0											
Cadmium	1.118											
Chromium	-0.036			X	X							
Cobalt	-.844											
Copper	16.898											
Iron	1367.159											
Manganese	14.631											
Mercury	0											
Molybdenum	0.304	X	X	X							X	X
Nickel	-1.752											
Selenium	0.584	X	X	X	X	X	X		X			

Table 5-3. (cont.). Stations where bioaccumulation exceeded upper 95% prediction limit for reference site bioaccumulation.

August 2004

Analyte	95% UPL	SWZ01*	SWZ04	BST04	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Silver	0.563											
Strontium	25.473											
Thallium	0											
Tin	0.113	X	X	X		X	X					
Titanium	69.640											
Vanadium	2.850		X									
Zinc	97.589											
Total PCBs	0					X	X					
Total DDT	40.51											
Total PAHs	1996.48			X	X	X						

+ 95% upper prediction limit for reference site mean values, in mg/kg dw for metals, and ng/g dw for PAHs.

Table 5-3. (cont.). Stations where bioaccumulation exceeded upper 95% prediction limit for reference site bioaccumulation.

October 2004

Analyte	95% UPL	SWZ01*	SWZ04	BST04*	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Aluminum	940.5											
Antimony	0.128			X								
Arsenic	3.565			X								
Barium	4.710											
Beryllium	0											
Cadmium	1.118											
Chromium	-0.036											
Cobalt	-.844		X									
Copper	16.898											
Iron	1367.159										X	
Manganese	14.631											
Mercury	0											
Molybdenum	0.304											
Nickel	-1.752											
Selenium	0.584											

Table 5-3. (cont.). Stations where bioaccumulation exceeded upper 95% prediction limit for reference site bioaccumulation.

October 2004

Analyte	95% UPL	SWZ01*	SWZ04	BST04*	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Silver	0.563											
Strontium	25.473											
Thallium	0											
Tin	0.113							X		X		
Titanium	69.640											
Vanadium	2.850											
Zinc	97.589											
Total PCBs	0			X		X	X					
Total DDT	40.51											
Total PAHs	1996.48				X							

+ 95% upper prediction limit for reference site mean values, in mg/kg dw for metals, and ng/g dw for PAHs.

Table 5-4. Potential aquatic-dependent life impairment die to bioaccumulation of CoPCs (U = unlikely impaired).

February 2004

Analyte	SWZ01	SWZ04	BST04	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Aluminum	U	U	U	U	U	U	U	U	U	U	U
Antimony	U	U	U	U	U	U	U	U	U	U	U
Arsenic	U	U	Possible	U	U	U	U	U	U	U	U
Barium	U	U	U	U	U	U	U	U	U	U	U
Beryllium	U	U	U	U	U	U	U	U	U	U	U
Cadmium	U	U	U	U	U	U	U	U	U	U	U
Chromium	U	U	U	U	U	U	U	U	U	U	U
Cobalt	U	U	U	U	U	U	U	U	U	U	U
Copper	U	U	U	U	U	U	U	U	U	U	U
Iron	U	U	U	U	U	U	U	U	U	U	U
Lead	U	U	U	U	U	U	U	U	U	U	U
Manganese	U	U	U	U	U	U	U	U	U	U	U
Mercury	U	U	U	U	U	U	U	U	U	U	U
Molybdenum	U	U	U	U	U	U	U	U	U	U	U
Nickel	U	U	U	U	U	U	U	U	U	U	U
Selenium	U	U	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	U

Table 5-4. Potential aquatic-dependent life impairment due to bioaccumulation of CoPCs (U = unlikely impaired).

February 2004 cont.

Analyte	SWZ01	SWZ04	BST04	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Strontium	U	U	U	U	U	U	U	U	U	U	U
Thallium	U	U	U	U	U	U	U	U	U	U	U
Tin	U	U	U	U	U	U	U	U	U	U	U
Titanium	U	U	U	U	U	U	U	U	U	U	U
Vanadium	U	U	U	U	U	U	U	U	U	U	U
Zinc	U	U	Possible	U	U	U	U	U	U	U	U
PCBs as Arochlors	U	U	U	U	Possible	Possible	U	U	U	U	U
Benzo(a)pyrene	U	Possible	U	Possible	Possible	Possible	U	U	U	U	U
Napthalene	U	U	U	U	U	U	U	U	U	U	U

Table 5-4. (cont). Potential aquatic-dependent life impairment due to bioaccumulation of CoPCs (U = unlikely impaired).

August 2004

Analyte	SWZ01	SWZ04	BST04	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Aluminum	U	U	U	U	U	U	U	U	U	U	U
Antimony	U	U	U	U	U	U	U	U	U	U	U
Arsenic	U	U	U	U	U	U	U	U	U	U	U
Barium	U	U	U	U	U	U	U	U	U	U	U
Beryllium	U	U	U	U	U	U	U	U	U	U	U
Cadmium	U	U	U	U	U	U	U	U	U	U	U
Chromium	U	U	U	U	U	U	U	U	U	U	U
Cobalt	U	U	U	U	U	U	U	U	U	U	U
Copper	U	U	U	U	U	U	U	U	U	U	U
Iron	U	U	U	U	U	U	U	U	U	U	U
Lead	U	U	U	U	U	U	U	U	U	U	U
Manganese	U	U	U	U	U	U	U	U	U	U	U
Mercury	U	U	U	U	U	U	U	U	U	U	U
Molybdenum	U	U	U	U	U	U	U	U	U	U	U
Nickel	U	U	U	U	U	U	U	U	U	U	U
Selenium	Possible	Possible	Possible	Possible	Possible	Possible	U	Possible	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	U
Strontium	U	U	U	U	U	U	U	U	U	U	U

Table 5-4. (cont). Potential aquatic-dependent life impairment due to bioaccumulation of CoPCs (U = unlikely impaired).

August 2004 cont.

Analyte	SWZ01	SWZ04	BST04	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Thallium	U	U	U	U	U	U	U	U	U	U	U
Tin	U	U	U	U	U	U	U	U	U	U	U
Titanium	U	U	U	U	U	U	U	U	U	U	U
Vanadium	U	U	U	U	U	U	U	U	U	U	U
Zinc	U	U	U	U	U	U	U	U	U	U	U
PCBs as Arochlors	U	U	U	U	Possible	Possible	U	U	U	U	U
Benzo(a)pyrene	U	U	U	Possible	Possible	U	U	U	U	U	U
Napthalene	U	U	U	U	U	U	U	U	U	U	U

Table 5-4. (cont.). Potential aquatic-dependent life impairment due to bioaccumulation of CoPCs (U = unlikely impaired).

October 2004

Analyte	SWZ01	SWZ04	BST04	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Aluminum	U	U	U	U	U	U	U	U	U	U	U
Antimony	U	U	U	U	U	U	U	U	U	U	U
Arsenic	U	U	U	U	U	U	U	U	U	U	U
Barium	U	U	U	U	U	U	U	U	U	U	U
Beryllium	U	U	U	U	U	U	U	U	U	U	U
Cadmium	U	U	U	U	U	U	U	U	U	U	U
Chromium	U	U	U	U	U	U	U	U	U	U	U
Cobalt	U	U	U	U	U	U	U	U	U	U	U
Copper	U	Possible	U	U	U	U	U	U	U	U	U
Iron	U	U	U	U	U	U	U	U	U	U	U
Lead	U	U	U	U	U	U	U	U	U	U	U
Manganese	U	U	U	U	U	U	U	U	U	U	U
Mercury	U	U	U	U	U	U	U	U	U	U	U
Molybdenum	U	U	U	U	U	U	U	U	U	U	U
Nickel	U	U	U	U	U	U	U	U	U	U	U
Selenium	U	U	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	U

Table 5-4. (cont.). Potential aquatic-dependent life impairment due to bioaccumulation of CoPCs (U = unlikely impaired).

October 2004 cont.

Analyte	SWZ01	SWZ04	BST04	BST07	DAC02	DAC03	2229	2238	2243	2433	2441
Strontium	U	U	U	U	U	U	U	U	U	U	U
Thallium	U	U	U	U	U	U	U	U	U	U	U
Tin	U	U	U	U	U	U	U	U	U	U	U
Titanium	U	U	U	U	U	U	U	U	U	U	U
Vanadium	U	U	U	U	U	U	U	U	U	U	U
Zinc	U	U	U	U	U	U	U	U	U	U	U
PCBs as Arochlors	U	U	Possible	U	Possible	Possible	U	U	U	U	U
Benzo(a)pyrene	Possible	Possible	Possible	Possible	Possible	Possible	U	U	U	U	U
Napthalene	U	U	U	U	U	U	U	U	U	U	U

6.0 DISCUSSION

6.1 SUMMARY OF IMPAIRMENT AND LIKELY SOURCES OF CoPCS

Based on measures of chemical contamination and toxicity in this Phase II TMDL study, the greatest impacts to aquatic-dependent life were observed in samples collected in February 2004. Less severe impacts were observed in the August and October sampling periods. These data imply that greater impacts occur during the wet season than in the dry season, and this is supported by other regional sediment studies (Brown and Bay 2005; personal communication Chris Stransky, Nautilus Environmental). February sampling was conducted just after a significant rainfall event (1.41 inches fell between February 21st and February 22nd). In contrast to February, no rain fell in the San Diego area in the 3 months preceding the August 11 sampling event, and only a moderate amount of rain fell in the two days preceding the October 19th sampling event (0.81"). However, conclusions regarding the influence of seasonal rains are constrained by the lack of additional wet season data in the current project. Except for results of the July 2003 Phase I study, no current wet season data is available for these study sites. While these results suggest greater impacts may be associated with seasonal stormwater inputs, more detailed analyses of contaminant loadings are required as part of Phase III TMDL studies. Impacts and possible sources of sediment-associated contaminants in the three study areas are summarized below.

6.1.1 Switzer Creek

The weight-of-evidence of chemistry, toxicity, and benthic community analyses suggest Switzer Creek study area was the most impacted of the three study areas considered in this project, and observed impacts were greatest in February. Switzer Creek sediments were highly contaminated by chlordane in February, and station SWZ01 was also contaminated by relatively high concentrations of total PCBs. Based on results of the two toxicity tests, the highest magnitude of toxicity was observed in Switzer Creek sediments in February 2004. In addition, Switzer Creek sediments had the most impacted benthic communities of the three sites studied in this project (in August).

Two lines of evidence suggest that organic contaminants are the cause of toxicity in Switzer Creek sediments. First, amphipod mortality was highly correlated with chlordanes and PCBs in San Diego Bay sediments. In addition, amphipod mortality was weakly correlated with mixtures of contaminants in these samples. These results were corroborated by the solid-phase and elutriate TIEs, which showed that treatments that reduce bioavailabilty of organic chemicals significantly reduced amphipod mortality in SWZ01 sediment. Based on the chemistry of these samples, chlordane is a likely candidate for future studies. Chlordane was also identified as a primary CoPC in this study area in previous BPTCP studies (Fairey et al. 1996), and this pesticide was identified as an important contaminant in the Chollas and Paleta Creek studies (SCCWRP 2004). Relatively low concentrations of contaminants were measured in *Macoma nasuta* tissues after exposure of clams to Switzer Creek sediments. Relative to TRVs, impairment due to elevated tissue concentrations of benzo(a)pyrene, selenium, and copper was considered possible in this study area.

Likely sources of contaminants responsible for aquatic life impairment in the vicinity of the Switzer Creek study area were discussed in Fairey et al. (1996). The most obvious source is the storm drain entering this system directly south of the 10th and Imperial Avenue Trolley station. This storm water system drains approximately 11 square kilometers of residential and industrial areas. Based on the contaminants of concern (chlordanes and PCBs), and the fact that greater contamination and toxicity were apparently associated with stormwater inputs, this storm drain is a likely source. Other possible sources of metal and PAH contamination in the Switzer Creek study area discussed in Fairey et al. (1996) included shipyard and ship off-loading activities associated with the 10^{th} avenue Marine Terminal and Campbell Industries. Because this site was dredged in September 2002, it is less likely historical sediment contamination associated with these activities were a significant source of the pollution observed in the recent study.

6.1.2 B Street/Downtown Piers

The weight-of-evidence of chemistry, toxicity, and benthic community analyses suggest B Street/Downtown Pier study area was the least impacted of the three sites considered in this project. The greatest impacts in this area were observed in samples collected in February 2004. B Street/Downtown Pier sediments at station BST01 were highly contaminated by copper in February 2004, but little toxicity was observed in this sample, probably due to lack of bioavailability. This is supported by the relatively low concentrations of copper detected in clams exposed to this sediment. Based on results of the two toxicity tests, the highest magnitude of toxicity was observed in B Street/Downtown Pier sediments in February 2004, but all of the samples from this area were considered to demonstrate low toxicity based on the LOE criteria. Chemical analyses of B Street/Downtown Pier sediments showed this site to be contaminated by higher concentrations of PAHs that the other two study areas, but no samples exceeded the total PAH consensus-based guideline value. Benthic community structure was considered to be highly impacted in two stations in this area (in August 2004). Relatively low concentrations of contaminants were measured in Macoma nasuta tissues after exposure of clams to B Street/Downtown Pier sediments. Relative to TRVs, impairment due to elevated tissue concentrations of benzo(a)pyrene, selenium, and PCBs was considered possible in this study area.

Likely sources of contaminants of concern in the vicinity of the B St/Downtown Piers study area were discussed in Fairey et al. (1996). These include stormwater runoff and commercial shipping activities. Based on the contaminants of concern (PAHs, copper), and the fact that greater contamination and toxicity were apparently associated with stormwater inputs, local storm drains are a likely source.

6.1.3 Downtown Anchorage

The weight-of-evidence of chemistry, toxicity, and benthic community analyses suggest the Downtown Anchorage study area was moderately impacted, and as with the other sites, impacts were greatest in February 2004. Downtown Anchorage sediments were contaminated by of chlordanes and PCBs. Based on the LOE for chemical contamination, Downtown Anchorage sediments were considered to be moderately contaminated. Based on amphipod mortality, the highest magnitude of toxicity was observed in DAC04 sediments in February 2004.

Evidence from the TIE conducted using DAC04 sediment suggests toxicity to amphipods in this sample was due to organic chemicals. As was observed in Switzer Creek and the Chollas Creek and Paleta Creek study areas, elevated concentrations of chlordane were measured in sediments from this area. Likely sources of contaminants in the Downtown Anchorage area are a large storm drain and numerous smaller storm drains near station DAC04. These convey runoff from parking lots and light industrial and commercial areas (Fairey et al. 1996 and references therein). These authors also suggested runoff inputs from the adjacent San Diego International Airport as a possible source of contamination in this area.

6.1.4 Reference Stations

The five reference stations used in the present study have been considered to represent backround conditions in previous studies in San Diego Bay. Four of the stations used in the current study (reference stations #2238, 2243, 2433, and 2441) were used in the study of Chollas and Paleta Creeks (SCCWRP 2004). The range of depths, grain sizes, and TOC values measured in samples from these stations were comparable to values reported from the previous study (see Table 7-1; SCCWRP 2004). Two of these stations were also used in the study of temporal impacts at Chollas and Paleta Creeks(# 2243 and 2433), and values reported in that study were also comparable to those of the current study (Brown and Bay, 2005).

In the current study, amphipod survival in selected reference sediment samples was lowest in February 2004. Lower amphipod survival was observed in samples from reference stations #2238, 2243, and 2441 in February 2004. Lower amphipod survival continued to be observed in sediment from reference station #2243 during all three sample periods (mean survival = 64%). It is not clear why survival was consistently low at this station during the current study, but Brown and Bay (2005) also reported low survival at station #2243 in February 2002 (65% amphipod survival), as did SCWWRP et al (2004) in samples collected in July 2001 (amphipod survival = 50%). The cause(s) of amphipod mortality at this and other reference stations should be the subject of future studies in San Diego Bay, and these should include TIEs at reference stations. The range in toxicity observed in the other reference station samples in the current study were comparable to those reported previously.

The station with the highest TOC values (#2441) also contained the highest concentrations of contaminants, but this and the other reference stations contained low concentrations of contaminants relatively to the LOE criteria. Based on the other sediment quality indicators, the reference stations used in the current study demonstrated relatively unimpacted benthic community structures, and minimal bioaccumulation of contaminants occurred in clams exposed to these sediments. This evidence suggests that the suite of stations used in the current study were representative of reference conditions in San Diego Bay.

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